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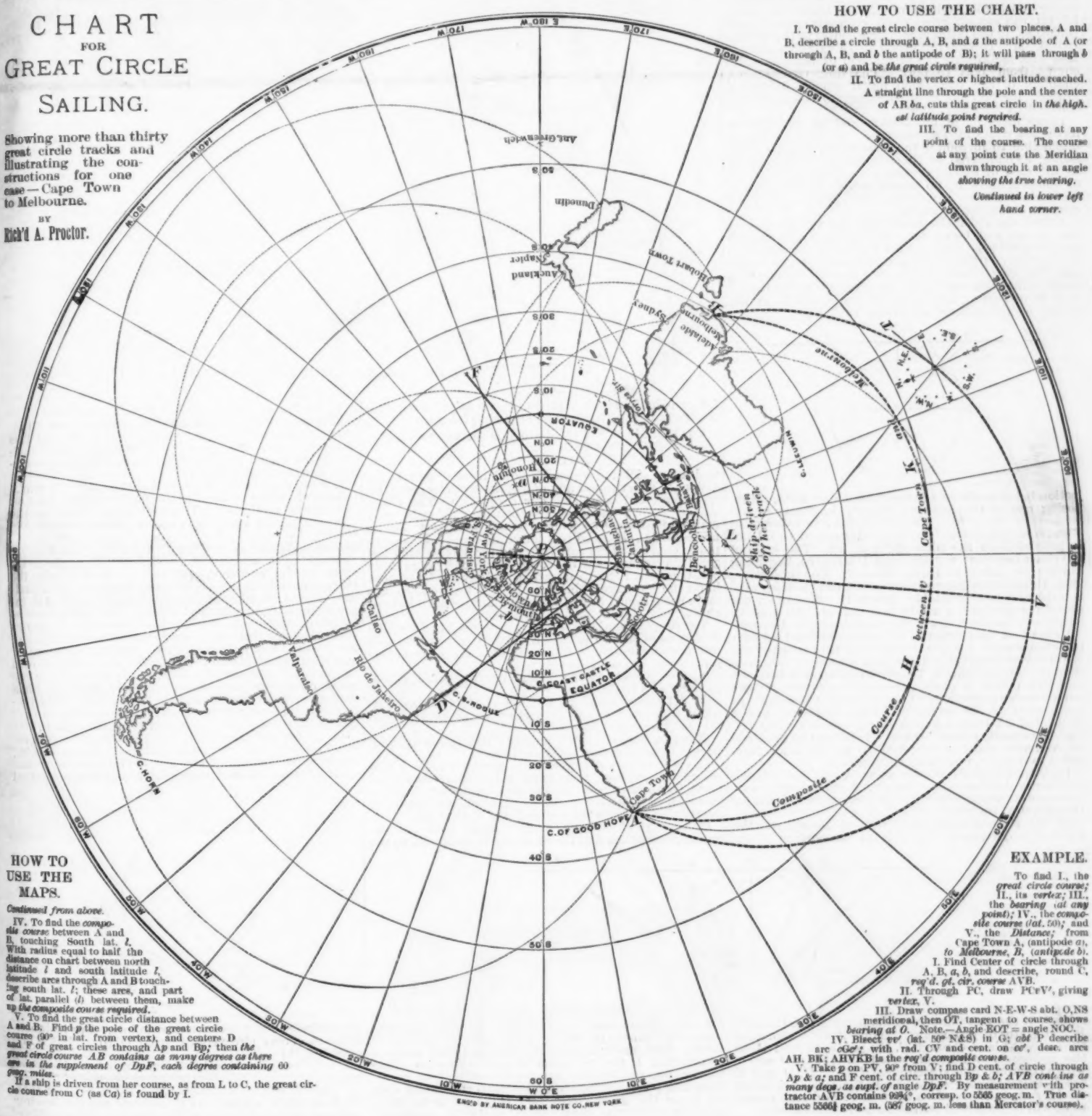
CHART FOR GREAT CIRCLE SAILING.

Showing more than thirty great circle tracks and illustrating the constructions for one case—Cape Town to Melbourne.

BY

Rich'd A. Proctor.


Arc Greenwich
Dunedin
Auckland
Napier
Hobart Town
Sydney
Melbourne
Adelaide
Melbourne
Cape Town
Ship driven from her course from L to C
Course
Composite
Callao
Valparaiso
Rio de Janeiro
C. HORN
C. ST. ROQUE
C. COAST CASTLE
EQUATOR
C. OF GOOD HOPE
Bombay
Calcutta
Madras
Pondicherry
Mauritius
Bencoolen
Singapore
Manilla
Canton
Hong Kong
Shanghai
Yeddo
Pekin
Sandwich Is.
San Francisco
Victoria
Vancouver Is.
Sitka
Behring's Str.
Aleutian Is.
Kamtschatka
Japan
Formosa
Philippines
Moluccas
Celebes
Java
Borneo
Sumatra
Ceylon
Arabian Sea
Persian Gulf
Red Sea
Mediterranean Sea
Gibraltar
Cape Horn
Cape Town
Melbourne
Sydney
Hobart Town
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Dunedin
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Adelaide
Melbourne

pens that the true great circle course would carry a ship into inconveniently high latitudes.

To meet the first difficulty, various methods have been from time to time suggested for obtaining graphically the great circle course. Sir George Airy invented a most ingenious but unfortunately a very complicated construction for drawing the great circle course on a Mercator's chart. Mr. Hugh Godfray, the author of the Cambridge text book on the Lunar Theory, suggested the use of the gnomonic projection, where the great circle course is represented by a straight line, just as the rhumb course is represented on a Mercator's chart; and various approximative constructions have been suggested from time to time.

To meet the second difficulty, Mr. Towson, of Liverpool, suggested composite sailing, by which a great circle course is taken from the port of departure to touch the highest latitude deemed safe, and another great circle course is taken which, touching that highest latitude, passes through the port of arrival; the journey pursued is along the former great circle course to the limiting latitude parallel, then along this parallel till the second great circle course is reached, and thence along the latter great circle course to the desired haven. Mr. Towson published also a valuable series of tables for facilitating the calculation of the composite course from port to port. The Rev. Geo. Fisher, chaplain of the Greenwich naval schools, devised a graphic method for approximating to the composite course on a Mercator's chart.

These methods of calculation and of construction have not come into general use. It has been found impossible to introduce the general use of great circle sailing as hampered by these requirements, especially in the case of sailing vessels, where fresh calculations or constructions by no means simple, would have to be made whenever a ship had been driven out of her course by stress of weather.

A chart on which the great circle course between any two points can be at once laid down would obviate these objections. And at first sight it seems as though Mr. Godfray's proposition met this want; for, as I have said, the great circle course on a gnomonic chart is a straight line. But a gnomonic chart cannot show so much as a hemisphere. The point of projection is at the center of the sphere, as shown at O, Fig. 1, the projection being made on a tangent plane as BPA. Supposing one of the poles to be at P, the center of the projection, the points A and B would be projected at *a* and *b* respectively. The points D and E could not be projected on the plane BPA at all. The scale of the chart increases rapidly from P outward, becoming infinite for points 90 degrees from P. The projection, then, though it might serve for ports in one hemisphere, is evidently not available generally. Moreover, the gnomonic projection would not indicate the bearing (anywhere on the course), the vertex, or the distance.

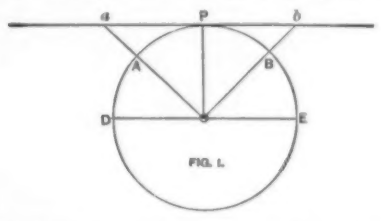


FIG. 1.

Instead of this practically useless method of constructing charts for great circle sailing, I propose the use of the stereographic projection, whereby (1) the construction for marking in the great circle course between any two points is made exceedingly simple; (2) the whole course is obtained at once; (3) the "bearing" at each point of the course is shown as plainly as the bearing of the rhumb course on a Mercator's chart; (4) the "composite course" where wanted can be obtained by a simple construction; and (5) the distance from point to point can be easily determined.

I need not here discuss the principles of the stereographic projection at any length. I will simply note those points which make the projection convenient for the proposed purpose.

In the stereographic projection of the sphere, the point of projection O, Fig. 2, is on the surface of the sphere, at the extremity of a diameter PCO, through P, the center of projection. Thus if *d* P *f* represent the tangent plane through P, the points A and B on the sphere would be projected on *d* P *f* at *a* and *b*, where OA and OB produced meet *d* P *f*. If D and E are 90 degrees from P (as in Fig. 1), their projections fall on *d* P *f* at *d* and *e*. So a point as F, and still nearer to O, will be projected on the tangent plane as at *f*.

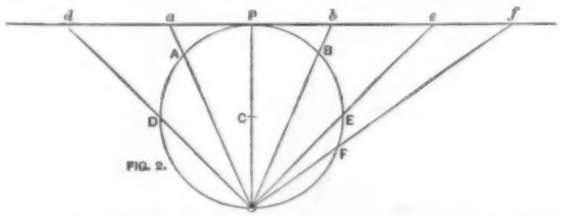


FIG. 2.

If P be either pole, the projection of the sphere on the plane *d* P *f* is a very simple matter; for all the meridians are projected into straight lines through P, and all the latitude parallels into circles around P as center. The radii of these circles can be obtained by construction, as shown in Fig. 2. But in practice it is far better to use their known lengths as indicated in trigonometrical tables. Thus if PB is an arc of 60°, we know that the angle POB contains 30°; so that P *b* is equal to PO tan 30°; thus, for the parallels corresponding to latitudes 85°, 80°, 75°, and so on, we take from the trigonometrical tables the natural tangents of 2½°, 5°, 7½°, and so on; and these numbers, with any convenient unit of length, give us the radii of the circles we are to describe round P. For instance, if we wish the equator to have a radius P *e* (equal to PO), five inches in length, we draw a line five inches long, divide it into ten equal parts, and one of these again into ten parts (or preferably make a plotting scale for the smaller divisions); then regarding one of the tenths of the line, *i. e.*, one-half an inch, as our unit, we take for our successive radii lines having the following lengths:

For latitude 85°	0·437	which is the tang. of	2½°
" 80°	0·875	"	5°
" 75°	1·317	"	7½°

and so on. Then a series of radial lines drawn to divisions 5° apart round any one of these circles gives the meridians, and completes our projection. The chart should have outlines of continents, islands, etc., marked in, for convenience, though in reality this is not essential, because the longitudes and latitudes of ports, etc., are alone really needed for determining the great circle course, and the course obtained by the simple constructions I shall indicate could always be plotted in on the Mercator's chart, to whose use seamen are more accustomed than to that of any other kinds of chart.

The properties of the stereographic projection which enable us at once to project a great circle course, and to determine bearings, distances, etc., on a stereographic chart, are the following:

(*a*) Every circle on the sphere, great or small, is projected into a circle.

(*b*) All angles, bearings, etc., on the sphere are correctly presented in the projection (a property found also in Mercator's projection).

With these properties I combine the following properties of great circles on the sphere:

(1) Since every diameter of a great circle is a diameter of the sphere, each point on a great circle is antipodal to another point on the same circle, or, in other words, if a great circle passes through any point, it passes also through the antipodes of that point.

(2) If a great circle touches a small circle on the sphere, it touches also the small circle antipodal to the former; for instance, if a great circle touches latitude-parallel 30° north, it touches also latitude-parallel 30° south. This needs no demonstration, being really a corollary of 1; for the point in which the great circle touches one small circle has for its antipode a corresponding point on the antipodal small circle, and also, by 1, on the great circle, and there can be no other point in which the great circle meets the antipodal small circle; for if there were, then, by 1, there would be corresponding points of contact or of intersection with the original small circle, which by our hypothesis is not the case.

To use the charts, however, the seaman need not concern himself either with the method of constructing them or with the principles on which their use in great-circle sailing depends. All he need care for is rightly to apply the constructions which result from these principles.

I propose to indicate only what are the processes necessary for the five following problems:

I. To find the great-circle course between any two points, as A and B, Fig. 3.

II. To find the vertex, V, or highest latitude reached, on that course.

III. To find the bearing at any point, as Q, on the course.

IV. To find the composite course, from port to port, touching any given limiting latitude.

V. To find the distance, A V B, to be traversed.

The constructions for these five problems are all included in the following simple statements (P, Fig. 3, is the pole, *e* EE' the equator), the italicized parts indicating the actual constructions, the rest giving the reasons and demonstrations:

I. *Find on the chart a and b the antipodes of A and B* (which of course is easy, as we have only to take off 180° on the meridians A P *a*, B P *b*, not shown in the figure to avoid crowding), and *a circle through any three of the points A, a, B, b, is a great circle of the sphere by* 1, *and must pass through the fourth point. Describe such a circle A B a b; A V B is the great circle course required.* [It will be best to take the three points A, B, and *b*, A being the point of departure. Pencil the bisecting-perpendiculars to *b*B, AB, intersecting in C, around which point as a center describe in pencil the circle AB*b*. Note whether it passes through *a*, for this serves as a test of the accuracy of the result. You may also note whether the points *e*' and E', in which it cuts the equator, are, as they should be, on the extremities of a diameter through P, for two great circles on a sphere necessarily intersect on a diameter of the sphere, and therefore, as P is the projection of the pole of the equator, two such points of intersection must lie on a straight line through P.]

II. *A straight line vPCV, through P and C, cuts the great circle course in V, the vertex required,* V being the highest latitude on one side of the equator, *v* that on the other. [V does not necessarily fall on the actual great circle course between two points. For instance, QB is the great circle course from Q to B, but V lies outside QB.]

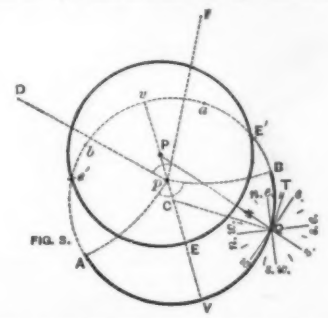
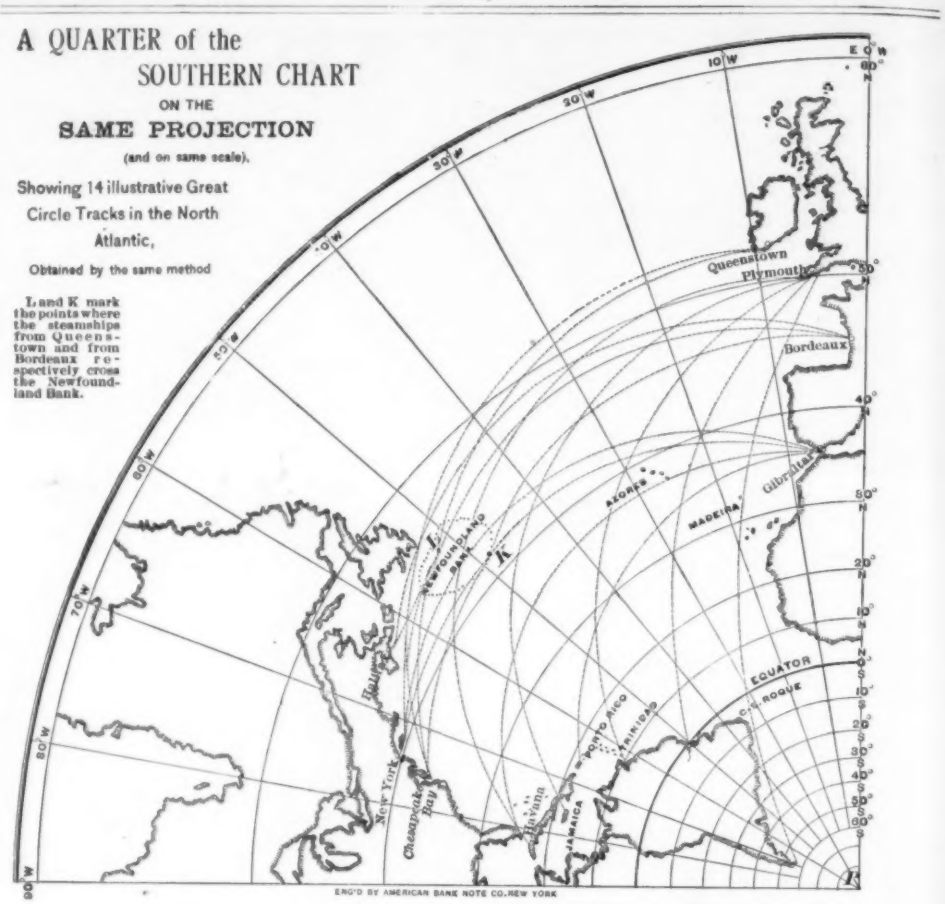


FIG. 3.

III. *Draw QT, tangent to the course, at Q. Then the angle PQT gives the bearing of the course at Q from the due northerly direction QP.* By observing that QT is at right angles to CQ, we can get the bearing without actually drawing QT. Thus in the case illustrated in the figure, the direction QT is north of due east by an angle equal to CQP, easily measured with a protractor.

IV. Suppose AVB, Fig. 4, the great circle course, to have its vertex V in inconveniently or dangerously high latitudes. *Let* L *on* PV *be the highest latitude which the ship must reach. Take l, antipodal to* L; then if we *bisect l* L, *in* G, and describe round P *as* center the circle *c* G *c*', it is obvious that any circle, HLK, having its center on *c* G *c*', and radius equal to GL or G *l*, will touch both the latitude parallels HLK and *klh*; and, by 2, will be a great circle. Therefore, *around* A *and* B, *as centers, with radius* GL, *describe circles cutting c* G *c*', *in c and c*', *and with c and c*' *as centers and the same radius describe circular arcs,* AH, BK, *touching the latitude parallel* HLK *in* H *and* K. *Then* AHKB *is the composite course required.* The distances along AH and BK can be determined by the method shown in the succeeding section, and the distance along the latitude parallel HLK is of course



easily determined, being an arc of a known number of degrees in a known latitude.

V. [We have to determine how many degrees there are in the arc AVB, not as it appears in the chart, but as it really is on the sphere.] *Take p, 90 degrees of latitude from* V *and v, Fig.* 3, *along v*PV. (This of course is done at once on the chart, which shows the degrees of latitude from the pole P.) Then *p* is the pole of AVB. *Find* D, *the center of the great circle* A *p, and* F, *the center of the great circle* B *p.* (This we do by I.; but most of the work is already done. We have the bisecting-perpendicular to B *b*, the bisecting perpendicular to A *a* passes through *c*; then the bisecting-perpendiculars to A *p*, *p* B, give us D and F at once.) What we want is to determine *the angle* A *p* B, between the arcs A *p*, *p* B; and it is obvious that this *is the supplement of the angle* D *p* F, which is easily measured with a protractor. *The number of degrees, multiplied by 60, gives the number of geographical miles, or knots, in the distance* AVB.

An example of these methods is given in the accompanying stereographic chart, where the same letters are used as in Figs. 3 and 4.

By a singular coincidence the distance actually determined by my construction for the great circle course

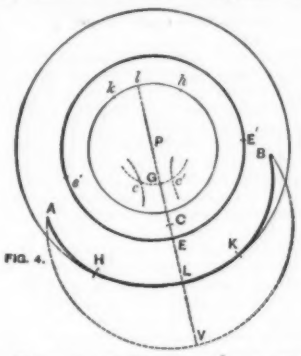


FIG. 4.

from Cape Town to Melbourne was 5,567 miles, the nearest result in whole numbers to the distance determined by calculation, viz., 5,566⅝ miles. But having obtained the angle 92° 47', I did not consider anything closer than 92¾° could fairly be used, giving the distance 5,565 miles (very close for a determination of this sort).

The distance between Cape Town and Melbourne on a rhumb course is 6,154 miles, *or 587 miles longer than the great circle course!*

The illustrative chart shows—of course, on a small scale only—the nature of charts on my plan. It has been carefully drawn, with meridians and parallels ten degrees apart correctly placed. The distortion is great outside the equator, but not greater than for high latitudes in Mercator's chart; nor does distortion at all affect the utility of such charts. (The stereographic and Mercator's projections are alike in showing small regions with little distortion.) More than thirty great circle paths are shown, but of course the charts published for sailors' use would be without paths of this sort, the object of the charts being to enable the seaman to lay down without trouble the track he has to pursue in order to traverse the shortest distance from any port whatever, *or from any point he may have reached on his journey*, to any haven.

The north pole being in this chart the center of projection, the northern regions are on a relatively small scale. Thus, the few great circle tracks shown on the Atlantic are not so well presented as the tracks in the southern seas, or from the northern to the southern hemisphere. The meridians and parallels of the chart serve, however, equally well for a map of which the south pole would be the center. I have constructed such a chart (the distortion affects Asia and North America very curiously), and the smaller map (a quarter of the chart) shows the North Atlantic as presented in this chart, the projection and scale being the same as for the larger chart. But a northern chart on a somewhat larger scale would suffice without any supplementary southern chart.

HOW TO FORM A HERBARIUM.

PLANTS designed for the herbarium should be prepared upon one's return from botanizing, if possible, or a few hours afterward. If they cannot be prepared until the next day or the day after, the plants must be left in the vasculum (Fig. 2), and the latter be placed in the cellar. But it is always best to prepare the plants as soon as possible after gathering them, except in the case of certain species that bloom early in the morning and soon afterward drop their petals. In such cases the preparation may be deferred until the next morning, when new flower buds will have expanded. The plants should not be all taken out of the vasculum at once (especially if the preparation is to take some little time), but one after another. If desired, all the specimens of the same species may be taken out at once, and then the box should be immediately closed.

The place of preparation should be dry, light, and airy. A large table supported by high horses, and allowing one to work standing without fatigue, is extremely convenient. In excursions to a long distance the botanist is often far from finding such a convenience, however, and has to have recourse to his bed or the floor as a substitute.

Upon the table should be laid, on one side, double sheets of paper; on the other, the driers; and in front, the plants to be prepared. The first thing to be done is to free the plant from the adhering dirt, without breaking the roots or other parts, by light and repeated blows and by the aid of the fingers. This done, one o. the double sheets of paper is opened and laid upon a drier, and a specimen spread out upon it in as natural a position as possible. If the plant is longer than the paper, its stem should be bent at a sharp angle near the top of the sheet, care being taken to previously compress or slightly crush the stem where the bend is to be made, so as to prevent it from snapping in two. The part of the specimen bent over should be separated as slightly as possible from the rest of the plant, especially if its length necessitates a second bending. Care should be taken to so arrange the specimen that its stem and branches and their primary ramifications do not injure the leaves or other organs of still more delicate texture. If the plant is very branchy at the summit, and, through its generally bushy or fastigiate ramifications of nearly equal height, projects beyond the paper, the preparation of it must be begun by placing the upper part of it on the paper in such a way that it does not project, and then bending back the main stem so that the roots point upward, but do not rest at all, or but slightly, upon any other organ of the specimen.

Before preparing a specimen that exceeds the length of the paper, there is one essential point to be first examined, and that is what part of it shall by preference be given the most prominence. It is difficult to establish a rule for this, for it is rather a question of tact and experience. With a little practice the student will easily become able to judge what should be done. Sometimes it will be the summit, and at other times the middle part or the base, that will be applied to the paper. After this, the parts that project above and below will be arranged in the most suitable manner. As a general rule, however, the specimen ought to be bent at that part that requires as slight a flexure as possible to be made.

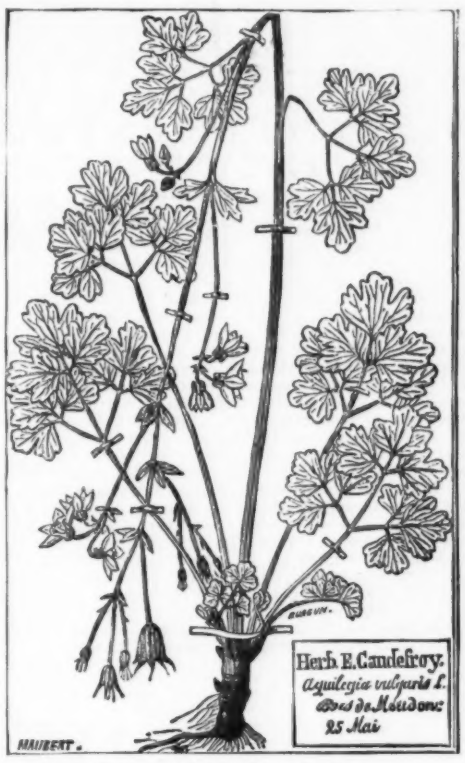


FIG. 1.—MOUNTED PLANT.

When the specimen is large, a single one may cover the sheet. If we are dealing with a small one, several may be laid down, until the entire sheet is covered. In this case care must be taken that no earth adheres to the roots to soil the flowers of the other specimens. If the specimens are of such a size that they can be placed side by side, they should be laid in opposite directions,

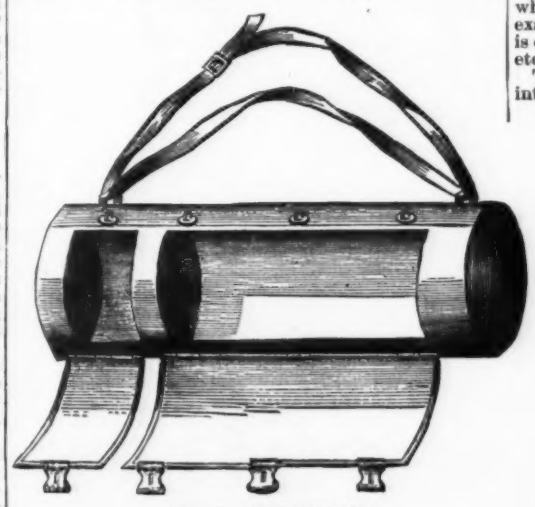


FIG. 2.—VASCULUM.

so that the flowers and roots of one shall not come into contact with the flowers or roots of the others.

The leaves should always be spread out with care, that is to say, they should not be allowed to assume other forms than those which they exhibit in nature. Yet, if they are not naturally plane, a few of them should be spread out flat so that the form and dimensions of the limb may be judged of, while the rest of them should be allowed to retain their natural habit. Moreover, the leaves should never be all arranged with the same surface upward, for it is necessary that both the upper and under surfaces shall be seen without having to turn the specimen over. If the leaves are too numerous, a few of them may be removed; but the removal should be done in such a way as not to give a false idea of their position upon the stem and branches. This may be accomplished by allowing their base to remain. The branches themselves, if too numerous, may likewise be removed in part, a sufficient number being left to give the specimen a form that in a manner recalls the general aspect of the plant. It is useless to add that, while endeavoring to preserve the plant's habit, we should also try to give the specimen a certain elegance of appearance.

As a general thing, the flowers should not be suppressed, unless the inflorescence is bulky. If it be too long, it may be bent as we have indicated with respect to the branches. Moreover, when collecting specimens, those always should, if possible, be selected which, while giving an idea of the general form of the species, are, as regards size, intermediate between the smallest and most robust individuals. In proceeding thus we need not have recourse to suppression or bending.

In the different plants in which the lower leaves exhibit no perceptible difference from the upper ones, two cases present themselves—either the upper part of the stem only or the entire plant may be dried. In the first case, if the inflorescence is developed, we may content ourselves with taking only the upper part of the plant, of the size of the sheet of paper; if not, we may, without inconvenience, cut specimens that shall be one or two times longer than the paper. In the second case, that is, if we desire to have the plant in its entirety, it should be cut 12 × 12 inches, and each part be prepared by itself, and the two be united after drying. This is the best way in which to prepare large plants, such as *Sonchus palustris*, *Epilobium hirsutum*, etc.

The flowers should be prepared with care, and without altering their natural arrangement. Yet, if the inflorescence consists of too large a number of flowers, and time does not permit of preparing all of them thus, it will be necessary to detach and dry some of them by themselves with particular care. This often becomes necessary, moreover, as a consequence of the bulk or number of the leaves or ramifications, which might prevent perfect desiccation, or break some portions of the flowers.

Polypetalous flowers should be opened and spread out in such a way as to allow their interior to be seen well. If irregular, it will be well to prepare each of their parts separately. In most cases it will answer to so place them that the special form of each division of the limb may be seen; but, whether they be regular or irregular, a few of them may be detached and dried by themselves, and arranged in the best way possible, either in their entirety or by splitting them longitudinally. It will prove serviceable in some cases, as for example in the labella of the *Cypripedia*, to interpose in their cavity either cotton or, with a larger number of plants, pieces of paper, so as to hasten the drying and render the study of them more easy later on.

Thus dried, these flowers may be glued to small sheets of white paper and put with the specimens to which they belong. In many cases, the study of the various parts of the flower will be considerably simplified by taking like precautions in the preparation of the calyces, stamens, pistils, etc. In the corymbiferous Compositæ (the Carduaceæ, among others), which sometimes have extremely large capitula, and the drying of which would be slow, and pressing difficult, the heads and stems may be split longitudinally and then separated. This process has the advantage of rendering the herbarium packages less distorted.

When once the specimens are arranged upon the sheet, the latter is closed and a drier put upon it. Another double sheet is placed upon this and covered with a drier, and so on, up to the last.

We may add that it is always extremely necessary to place a temporary ticket in the sheet with each species, giving the name of the plant, the date on which and the place where collected, the nature of the soil, the exposure, and the altitude at which it grew. In place of tickets, numbers may be substituted corresponding to those of a list in which are inscribed the data that precede.

When the last specimen has been taken from the box, there always remains a certain quantity of earth, which should not be thrown away until it has been examined, as it often contains different things that it is of interest to preserve, such as petals, bulbs, seeds, etc., as well as specimens of minute plants.

The entire collection, having been prepared, is put into the press (Fig. 3). It is essential, if the press be a screw one, like the one here represented, that the first pressure be not too great, but that it be slight at first, and be increased gradually in measure as the drying proceeds.—*Science et Nature.*

FIG. 3.—PLANT PRESS.

A NEW CHLORIMETER.

MR. J. FLEMING STARK, F.C.S., in a paper recently read before the Newcastle Section of the Society of Chemical Industry, describes a new form of chlorimeter intended for estimating the quantity of chlorine present in the air of the bleach chambers used for the manufacture of bleaching powder. The arrangement is also applicable for other purposes in connection with gas analysis. It comprises a burette for measuring the gas, which is connected by India rubber tubing with a reservoir of water, a small wash bottle, and an absorbing-tube. For convenience in operating, four of the

latter are mounted on a stand, each being connected to a main tube attached to the outlet of the wash bottle, and having a tap so that it can be brought into use or shut off as may be desired. Each absorbing tube is fitted with two tubes inserted through an India rubber stopper; one (to which a tube connected to the bleach-chamber can be attached) reaches nearly to the bottom, and is contracted as its lower end so as to break up the bubbles of gas; and the other (which is connected to the top and main tube) passes just through the stopper. The absorbing tubes having been charged with a solution of iodide of potassium, and the wash bottle charged with solution of iodide of potassium and starch, the burette is filled with water, and one of the absorbing tubes connected to the bleach chamber. By lowering the reservoir, gas can be aspirated through the absorbing tube into the burette; and the wash bottle acts as an index that all the chlorine is absorbed—as, if any escaped past the absorbing solution, it would have the effect of causing the liquid in the wash bottle to become blue. When 387·7 c. c. of gas have been passed into the burette, the aspiration is stopped. The contents of the absorbing tube are carefully washed out into a beaker, and titrated with decinormal arsenite of soda solution. The number of cubic centimeters of this solution required, multiplied by 2, gives the grains of chlorine per cubic foot of gas in the chamber.

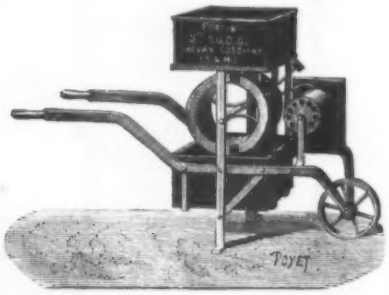
IMPROVEMENTS IN VELOCIPEDES.

THE bicycles, tricycles, etc., have come into use only as sporting articles, and but few attempts have been made to utilize these machines for practical purposes.

In the annexed cut, taken from the *Illustrirte Zeitung*, we show a tricycle made by H. Kleyer, of Frankfort a. M., Germany. It is to be used by public porters, messengers, delivery clerks, etc., for the transportation of goods and merchandise of all kinds. The wheels are mounted on an axle supporting two side bars, between which the box is hung. A steering wheel is placed at the rear. The driving shaft is operated directly by means of treadles and cranks, or by means of driving chains.

AN AGRICULTURAL MITRAILLEUSE.

MR. FORTIN, a mechanician at Chevry-Cossigny (France), has recently devised a mitrailleuse designed



for preserving mills, fields, and vineyards against the damage caused by the incursions of ravens, hares, boars, and jackals.

It consists of a cylinder containing 10 chambers for as many cartridges, and set in motion by a small overshot water-wheel, under the influence of which the charges are fired every hour or every two, three, or four hours, according to the will of the owner. Animals, frightened by the noise, go elsewhere to commit their depredations.

The apparatus is automatic. The small reservoir that supplies water to the wheel takes ten hours to empty, and is filled again from the vessel beneath, into which the waste water escapes.—*Science et Nature.*

RANGE OF GUNS.

IN answering a question on the range of modern guns the *Army and Navy Journal* says that the ranges of modern heavy guns are not tested for extreme ranges and at high elevations. Krupp, "Experiences de Tir," No. xlvii., Meppen, 17 Aout, 1884, gives the range of the 30·5 cm. rifle, 35 calibers long, at an elevation of 14 deg., as 10·165 meters. No. 44, Meppen, July 31, 1883, that of the 26 cm. rifle of 35 calibers length, with an elevation 20 deg., as 11·526 meters; projectile, 275 kilos.; initial velocity, 530 meters. At Gavre, 1880, the French 34 cm. steel rifle, with an elevation 38 deg., showed a range of 12·918 meters. The authority, Helie Balestique, II., pp. 204 and 278. The "Revue Maritime et Colonial" for May, 1885, gives the range of the new French rifled 21 cm. mortar as 3,944 meters, with 45 deg. elevation, and 3,212 with 60 deg. elevation. In his prize essay on "Improvements in the Art of War," Military Service Institution, 1882, Colonel Lazelle reports the following ranges: Krupp rifled 28 cm. (11 in.) howitzer of 1879, elevation 28½ deg., 8,000 yards; Krupp's 15 cm. B L. howitzer, steel, 45 deg., 6,550 yards; 200 lb. Parrott 4,272 yards, 11 deg. 47 min. elevation. American muzzle-loader, 11 in. rifle, altered, 6,038 yards with 14 deg. elevation; 8 in., 9,419 yards with 27½ deg. elevation. Of ten shots from Krupp's 4⅛ in. field gun fired at a horizontal target 11,300 yards distant, nine were included within 18 yards of lateral deviation. The greatest effective ranges of the European field guns firing common shell are given at from 5,000 to 8,000 yards; using shrapnel shell, 3,000 to 3,800 yards. Greene gives the following ranges of Russian guns: Bronze, 9 lb., 5,000 yards; bronze, 4 lb., 3,800 yards; steel, 4 lb., 7,000 yards. Maguire, in his "Attack and Defense of Coast Fortifications," gives the maximum range of the Krupp 15 cm. and 28 cm. guns with shell as 8,000 yards. None of these authors cite their authorities. The new French long-range cannon, De Bange system, sent to the Antwerp Exhibition, weighs 37 tons, is a fraction under 37 ft. in length, and throws a 1,000 lb. projectile a distance of 12 miles 752 yards (20 kilos.). The author of this new piece destined for coast defense is the ex-Colonel De Bange, now at the head of a large private firm, who is said to have retired from the service in disgust, and yet his guns, from the smallest mountain to the largest position piece, have been adopted by an ungrateful country.

THE EMPRESS BRIDGE OVER THE SUTLEJ.

THE accompanying plate gives the elevation and details of a bridge constructed in British India to cross the rivers Sutlej and Beas.

This bridge comprises 16 bays of 260 feet span, and piers founded at about one hundred feet below the level of low water (Fig. 1). The bridge passes through a natural sandbank which forms a sort of island in the middle of a river.

The piers, which are protected externally by rockwork, consist, each of them, of 3 metallic tubes placed along side of one another, and connected at their upper part by masonry which, in plan, has the form of a rectangle with rounded corners. The object of the rockwork just mentioned is not only to protect the piers, but also to cause a deepening of the river between each of them.

The abutments are formed of two piers which are constructed in the same manner as the river ones, but which are surrounded with ballasting and connected with a mass of dry stones. The extremity of the approaches is sustained by water-wings perpendicular to the axis of the work.

The external and internal diameters of the tubes that constitute the piers are respectively 18¾ and 18 feet. They are lined internally with wooden timbers, strongly bolted together and hooped, and are externally protected by a casing (Figs. 5 and 7).

The earth was excavated two feet beneath the lining, in sand, and 14¾ feet in clay. The tubes and the excavated portion beneath them were filled in with hydraulic beton. Above this was placed a layer of sand, and the tubes were closed with a mass of beton 9 feet thick. The depth of the foundations is thus, on an average, 108 feet. The bricks employed in this structure were baked until their surfaces were vitrified, in order to prevent them from being injured by salt water. The mortar consisted of one part of lime to two parts of brick dust and one part of hydraulic lime. These materials were carefully mixed in a dry state.

The girders are all of the lattice pattern. Their length, from axis to axis of the points of support, is 253 feet, and their weight, including the flooring, about 405 tons. The flooring is composed of plates of iron sufficiently strong to bear the weight of guns of the greatest caliber mounted upon carriages.

The bridge, in fact, was built in order to permit the English army employed in the last Afghan war to pass from one bank of the river to the other. In order to

Fig 5

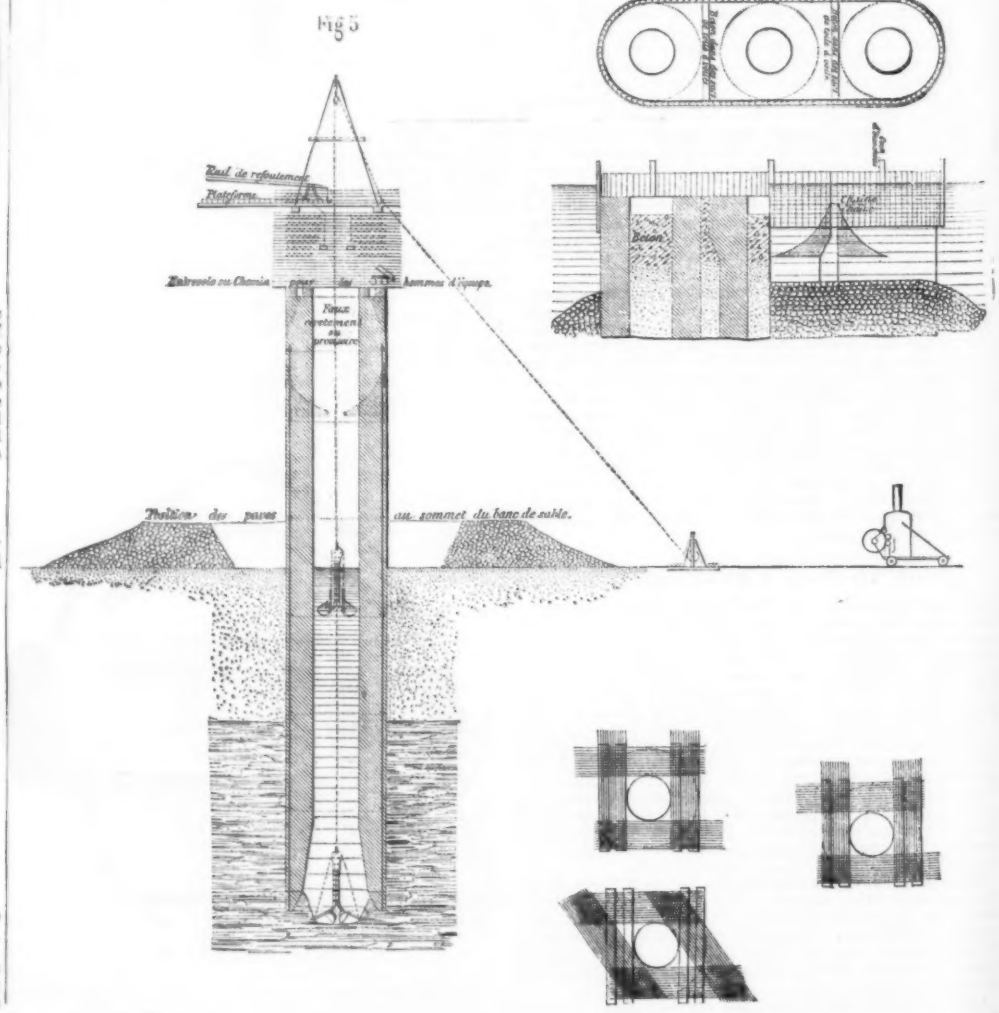


FIG. 1.—Elevation. FIGS. 2, 3, 4.—Arrangement of the Rails for Sinking the Tubes. FIG. 5.—Sinking a Tube

THE EMPRESS BRIDGE OVER THE SUTLEJ.

sink the tubes, rails laid across one another were used, as shown in Figs. 2, 3, and 4. These weights necessarily varied according to the course of the work. The tubes from 20 to 40 feet in height above ground were loaded with a pile of rails from 14¾ to 20 feet in height. In order to extract the sand from the interior of the wells, use was made of a dredge with jaws, whose buckets had a capacity of from 10 to 12 cubic feet. Ten of the wells were excavated through a very compact layer of clay that was thirty feet in depth beneath the surface of the natural earth. This clay was first attacked with pick and shovel, but, as slow progress was made thereby, recourse was had to the Gattmell excavator.

The dredge with jaws (Bull's system) consists of two buckets that are allowed to fall abruptly into the sand so as to permit their cutting edge to bury itself therein. After this the bucket is righted, so as to prevent the sand from escaping, and then drawn up. When the wells had been sufficiently excavated, the water that filled them was removed by means of leather buckets attached to the extremity of a chain that wound round a steam windlass.

Fig. 5 gives a section of a tube during the period of sinking, and shows the excavator and windlass.

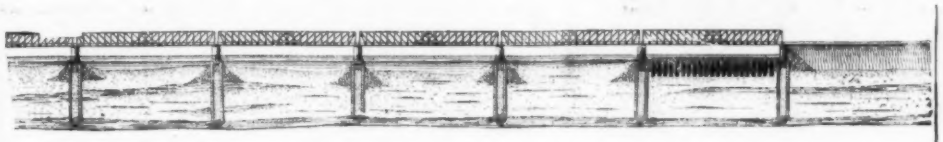
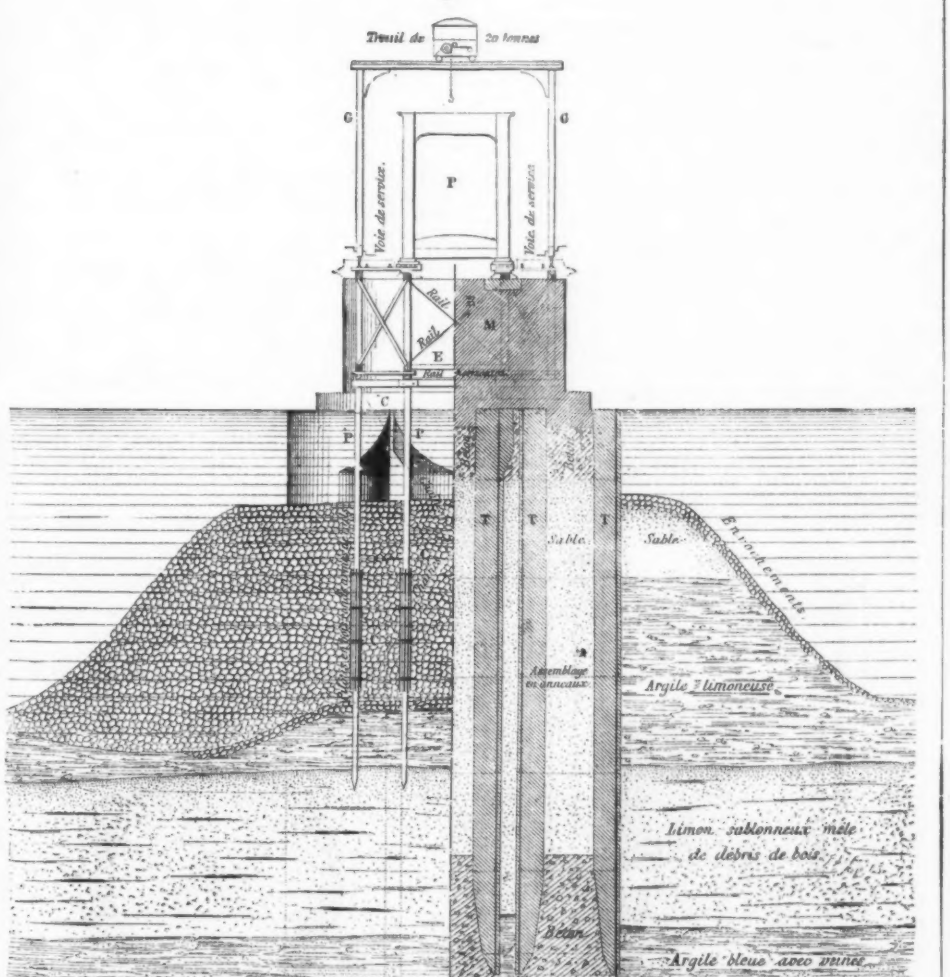


Fig 7



THE EMPRESS BRIDGE OVER THE SUTLEJ.

The effect that the removal of the water had was to increase the weight of the tubes, and consequently to accelerate their descent.

Fig. 6 gives a plan, elevation, and section of the cofferdam employed for constructing the masonry that rests upon the top of the tubes. As the parts of the bridge were of considerable weight, their carriage was facilitated by arranging inclined, greased rails upon the service bridge (Fig. 7).

The materials were raised by four rolling cranes 20 feet in height, and having a sweep of 20 feet. One of these cranes is shown in Fig. 7.—*Annales des Travaux Publics.*

DESCRIPTION of FIG. 7.—P. Transverse section of the bridge. G. Crane. M. Masonry. E. Crossbracing of rails. PP. Wooden posts provided with rails. T T. Tubes filled with beton. CC. Chains for strengthening the piers, PP.

TEST FOR GELATIN.—Vogel, the author, adds ammonia to a 10 per cent. solution of silver nitrate till the precipitate is redissolved, and mixes this liquid with an equal volume of the solution of the gelatin under examination. If the gelatine is impure, the mixture takes a yellow or even a brown color.

ELECTROLYTIC REFINING OF COPPER.

A LONG article or essay on the above subject has just appeared in the German *Berg und Huttenmannische Zeitung*, written by Dr. Martin Kiliani, of Munich, who has previously published several very interesting communications on electro-metallurgy, and who is himself the patentee of a process for the extraction of zinc.

This article cannot fail to be of considerable interest to all who are desirous of understanding the principles concerned in the electro-metallurgy of copper. We have once or twice, in notes on the subject, alluded to the great secrecy with which those works now employing the process continue to surround the matter. Dr. Kiliani alludes also to this in the case of the German works, and speaks of this secrecy with considerable impatience. He says that its effect has been to some extent to make people believe that the operations carried on are based upon discoveries only known to a few, and are surrounded by difficulties of a very special and complicated nature. He writes the article now in question with the object of dissipating this wrong impression, and of convincing all those interested in the subject that whatever is done inside these works can be done by anybody who gives a little attention and study to the subject, the only "secrets" being slight and immaterial details of practice. He commences by a slight review of the history of the subject, and gives to Maximilian, Duke of Leuchtenberg, the honor of being the first discoverer of the fact that by electrolytic action an impure copper containing precious metals can be refined so as to yield pure copper and leave the precious metals in a concentrated form ready for further treatment. This was in 1847, and the chemist in question not only discovered the fact, but went a considerable way in investigating and explaining the various principles and reactions concerned. He also appreciated the very important bearing this discovery might eventually have on practical metallurgy.

But nothing further came of it, practically speaking, till it was again taken up by Elkington, in England, who took out patents about 1865, not limiting himself to the refining of impure metallic copper, but including in his operations also the sulphide of copper, or copper regulus. This was prepared in the usual manner by smelting copper ore, which was cast into slabs for use as anodes in the baths of copper sulphate. Rods of copper were cast into the regulus slabs to serve as supports and conductors, and these rods were themselves protected from the action of the solution by coating them with wax. Dr. Kiliani describes Elkington's arrangements, and states that with three Wilde machines the production of pure copper was at first 200 to 250 kilos. per 100 baths per 24 hours, and that in 1878 Elkington's plant produced six tons per week.

But however simple this process seems in outline, says the author, there are many points which would bring great difficulties to an inexperienced person attempting the use of it, if he desired to get, not only silver and gold, but also a good quality of copper. These points depend on the presence of such impurities as arsenic, antimony, bismuth, etc., and on the necessity of carefully observing certain conditions as to strength of current, composition, and circulation of the solution, etc. Elkington, in his patents, does not deal with these points, and this is perhaps the reason, together with the lack of suitable dynamo-machines, why the electro-metallurgy of copper did not make much progress beyond Elkington's works till within the last few years. It is really only during the last decade that the immense progress of electro-technics has extended also to metallurgy, and enabled great successes to be realized in the working of copper, and opened up the prospect of equal successes in other directions.

The two most successful recent examples of the application of electrolysis to the metallurgy of copper in Germany are the Hamburg refinery, working with Gramme machinery, and the copper works at Oker, in the Hartz, where a very extensive plant has been fitted up by Siemens and Halske, of Berlin. These are the two works specially alluded to by the author in his remarks about secrecy.

Proceeding to examine into the nature of the process itself, Dr. Kiliani begins by saying that the basis of the whole matter consists in the simple fact that when an alloy of several metals forms the anode in a bath, the electric current does not cause the solution of all the component metals at the same time, but that it makes a selection and takes one metal after the other in a certain order; and similarly when several metals are in solution in a bath, the current selects them in a certain order for deposition on the cathode. A fully satisfactory scientific explanation of these facts cannot, according to the author, be attempted, because the whole matter is even yet too little studied, and the materials for a full explanation have not yet been collected. Even as concerns the order of this solution and deposition there are only full materials published concerning silver, copper, iron, zinc, and lead, and then only so far as concerns some few electrolytes. About those elements which are specially troublesome and important in the metallurgy of copper, arsenic, antimony, bismuth, etc., the published information is very superficial and scanty, and in some instances quite incorrect.

The author then states that "the selection of the different metals takes place, in general, on the principle that as much energy as possible is created ('erzeugt'), and as little energy as possible is consumed." That is to say, under conditions to be explained later on, that metal will be first dissolved from the anode, the solution of which causes the development of the greatest amount of energy (electromotive power); and that metal will be first deposited from a solution on to the cathode, the separation of which requires the least consumption of this same energy.

A comparative measure of the energy required in these cases is obtained by taking the heat of combination of the metals with oxygen to form oxides or salts. The combination heat of the metals with oxygen to form oxides is taken by the author to form a tabular list in the order in which they are dissolved, as follows: Manganese, zinc, iron, tin, cadmium, cobalt, nickel, lead, arsenic, bismuth, antimony, copper, silver, gold.

Of this list it may be said that all those metals which precede copper, when they are present in the anode as metals (not oxides) together with copper, will be attacked by the current before the copper, whereas silver and gold will only be dissolved after the copper, or if they are present in very small amount, they will fall from the anode as powder, and be found in the "mud" of the bath. In practice this order is fully maintained, and all the above metals dissolve before the copper, and are found in solution in the electrolyte, unless they form insoluble compounds, for example, with lead when the bath is a sulphate, as in refining copper. When the metals are once in solution, their deposition on the cathode takes place in reverse order, beginning with gold and ending with manganese. But the correctness of these rules is dependent upon several conditions, which must be observed in order that the work may go on in a normal manner. The chief of these conditions concern the strength of current, the nature and concentration of the electrolyte, the proportions of the metals alloyed together in the anode, and the physical condition of the anode itself.

If the current exceeds a certain strength, all the metals may be dissolved and deposited together. The more neutral the electrolyte is, the more easily will the more electro-negative metals be dissolved and the more easily will the more electro-positive metals be deposited. The same be said of the electrolyte, the poorer it is in copper in solution. If the anode consists of copper containing a large amount of impurities, these will be dissolved more easily than from a copper containing but little impurity. The less dense and compact the anode is, the better the process will go on.

This all applies only to copper containing the other metals in the metallic form. If oxides or sulphides are present, the first question is as to their conductivity for the current. Most oxides may be classed as non-conductors under the conditions of the bath, and have nothing to do with the action of the current, they simply go into the insoluble mud, or are dissolved by the purely chemical action of the electrolyte.

The sulphides are mostly good conductors, but not nearly as good as metallic copper. If therefore but a small amount of sulphides is contained in the copper of the anode, the current will act only on the copper, and the sulphides will be found in the mud unacted upon, unless by the acid of the bath. If much sulphide is contained in the copper, the current will be more or less divided between copper and sulphide, and a portion of the latter will be decomposed with separation of sulphur.

In addition to the above secondary reactions of the bath, there are also others, some of which are good and some bad, for conducting the process. The current is always striving to decompose the electrolyte into metal

(or oxide) and acid; while this liberated acid is striving to redissolve the deposited metal or oxide. These two forces are always opposed to one another, and under varying conditions either may gain the upper hand. The resolvent action of the acid, in cases where the components of the electrolyte have a strong chemical affinity, may overpower the action of a weak current.

In the case of copper this secondary action is not of much importance, copper not being acted upon by dilute sulphuric acid in the absence of air, but still it is quite noticeable in presence of good circulation of the liquor, and more or less access of air in the cathodes. A favorable effect of this secondary action is that any cuprous oxide which may be deposited at the cathode with the copper, owing to weakness of current, is dissolved again.

The author then proceeds to give a list of the special impurities to be met with in copper, and the behavior of each of these during electrolysis. These statements are based upon a very extensive series of experiments made in the laboratories of the Technical High School at Munich, the author having for a long time paid very special attention to electro-metallurgy in all its branches.

The experiments, the results of which are given below, were all, where not specially otherwise stated, carried out with a normal electrolyte containing 150 grammes of copper sulphate and 50 grammes concentrated sulphuric acid per liter.

The normal current used, the author expresses by the formula :

$$20 \frac{\text{amperes}}{\text{square meters.}}$$

Cuprous Oxide.—Cuprous oxide, being a bad conductor, is not affected by the current, and goes first of all into the mud of the bath. It is then, however, dissolved by the free acid, more or less according to the time the mud is allowed to remain in the tank. Therefore any cuprous oxide contained in the anodes diminishes the free acid of the electrolyte, and increases the amount of copper in solution.

Sulphide of Copper.—If the amount of this does not exceed that usually present as impurity in "black copper," and especially if it is all present as cuprous sulphide (Cu_2S), which is non-conducting, it all goes into the mud, from which no free sulphur can be extracted by carbon disulphide. If the copper sulphide is present to the extent of a considerable percentage of the anode, it is decomposed with liberation of sulphur.

Silver, Gold, Platinum.—These are all left undissolved in the mud as long as they are not present in considerable quantity, and as long as the liquor retains its proper normal composition as to free acid and dissolved copper. If the liquor gets to be neutral, silver is soon dissolved, and is then of course deposited with the copper on the cathode.

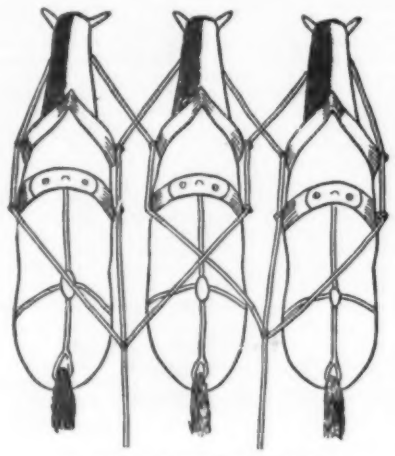
Bismuth and Oxide of Bismuth.—These go partly at once into the mud as insoluble basic salt, partly into solution, from which they then eventually precipitate as basic salt. Thus the presence of metallic bismuth in the anode causes the liquor to become poorer in copper, while the presence of oxide of bismuth causes a reduction in the amount of free acid. No bismuth was found at the cathodes, even in cases where large quantities of the basic salt had already deposited in the mud, so long as the bath was kept in its normal condition as to copper and acid.

Tin.—This is dissolved in the bath, and after some time is partly precipitated again as basic salt. If the anode contains very much tin, the greater part remains as basic sulphate, adhering to the anode itself. This deposit on the anodes is a dirty light gray in color when moist. It is white when air-dried, and increases rapidly in weight, even after long drying at 100 deg. Cent. It contains sulphuric acid, and the tin oxide in it is mostly of the variety soluble in hydrochloric acid, the variety insoluble in that acid being present only in small amount. The presence of tin, therefore, lowers the amount of copper in the bath without replacing it by any appreciable amount of tin in solution. It also, in consequence of the separation of basic salts, increases the amount of free acid, but only to a slight extent. The tin in solution exercises a surprisingly favorable influence on the copper deposit on the cathode. Copper precipitated from a neutral solution of pure copper is obtained in a rough, irregular, and brittle form, but if the copper contains tin, the deposits are excellent and tough. This was the case with deposits in which no trace of tin could be detected. The resistance of the bath is also much reduced by the presence of tin in the anodes. This action of tin does not seem to be as yet understood sufficiently to admit of an explanation.

Arsenic.—Arsenic, if present in the metallic form, goes into solution as arsenious acid, and only appears in the mud when the solution is saturated with it. Arsenic in the form of arsenic acid combined with oxide of copper, or other oxides, is deposited as mud at once in neutral solutions, as these oxide combinations are non-conductors. In acid solutions arsenic acid is slowly dissolved by secondary action of the acid into the solution. Metallic arsenic thus reduces the amount of copper and increases that of free acid in the bath, because it goes into solution without combining with an equivalent of acid, while at the same time a proportionate amount of copper is deposited with liberation of acid. Combinations of arsenic acid cause a slow neutralization of free acid. Arsenic does not enter into the copper deposit on the cathodes so long as the bath remains normal as to copper and free acid. In a neutral bath, or in one in which the copper in solution is insufficient, arsenic is deposited with the copper.—*Engineering.*

REINS FOR THREE HORSES ABREAST.

THERE are numerous methods for arranging the reins for driving more than two horses, but the idea on this subject of Mr. William Toole, of Sauk Co., Wis., seems to possess many practical features deserving of description and illustration, the accompanying engraving showing the operation referred to. The ordinary two-horse lines are used for the outside horses, the branch lines being snapped into the bit of the middle horse. The additional branch lines employed are about six inches longer than on the others, and have buckles for adjusting their length, and a snap at each end. The branch lines should be run through the rings of the middle harness and snapped into the bits of the outside horses. The other ends should be crossed over the back of the middle horse and snapped into the buckle of the reins. The method is accurate, easy of adjustment, and allows the horses driven a free and facile



ADJUSTMENT OF REINS.

movement, while it gives the driver a good control over their motions.—*Horseshoer.*

THE DOWSON GAS APPARATUS.

HEATING and motive power are our principal auxiliaries in commercial industry; and in these days of great labor for small profits, it is obviously necessary to procure their aid in as efficient a manner and at as low a cost as possible. The great value of gas as a cleanly and regular means of heating, and, in conjunction with gas engines, of giving motive power, is becoming more and more recognized. The only drawback to its more extended use is the high price at which town gas is usually supplied, and the considerable outlay needed to establish coal-gas works on a small scale in isolated places. The time is therefore ripe for the introduction of apparatus to supply this great want, and it is such apparatus, introduced by the Dowson Economic Gas Company, that we now propose to notice. When the British Association met at York, in 1881, Mr. J. Emerson Dowson read an interesting paper on the production of a cheap gas for motive power, which paper was well received. We had the pleasure of hearing that paper read, and of afterward seeing Mr. Dowson produce the gas for driving an Otto gas engine in an exhibition near the old Minster. Since that time the Dowson system of manufacturing cheap gas has made great strides, having been applied in a large number of works with marked success, notably in the new establishment of Messrs. Crossley, of Manchester, where the Otto gas engines are so extensively made. These works, and the manufacture and application of the Dowson gas there, were described

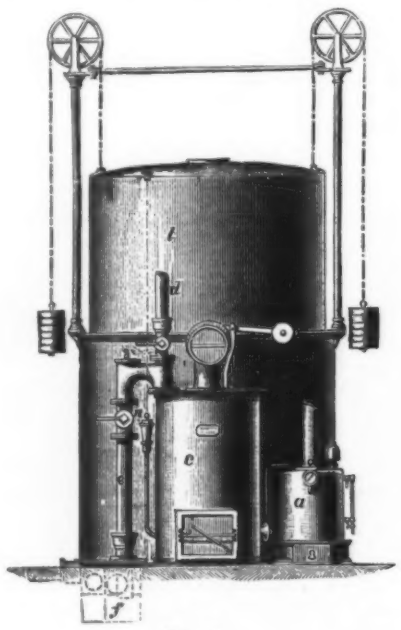


FIG. 1.

THE DOWSON GAS APPARATUS.

and illustrated by us at the time, namely, in July, 1884. In order, however, to bring the history of the progress of this invention down to date, we illustrate herewith its latest development. The Dowson cheap gas is made by passing a mixture of superheated steam (produced in a small boiler of special construction) and air through a mass of incandescent fuel contained in a generator. There is no exterior fire, and the cost of repairs is said to be but trifling. The apparatus is simple and easy to work. To make 1,000 cubic feet, only 13 lb. of coal and about 7 pints of water are required. The gas is cleansed by passing it through a scrubber charged with coke moistened with water. Even where anthracite costs 20s. a ton delivered, this gas can be made on quite a small scale at an average cost of threepence per 1,000 cubic feet, including an allowance for the wages of attendant, repairs, etc. For general purposes about four times, and for the Otto gas engine about five times, more of this gas than of ordinary coal gas are required to develop the same power—the price of 3d. should therefore be multiplied by 4 or 5, or say 1s. to 1s. 3d. for the equivalent of 1,000 cubic feet of coal gas, which usually costs from 3s. to 4s. When made on a large scale, the cost of the Dowson gas is still less. In the above estimates the price of anthracite is taken at 20s., to cover districts far from the pits; but in many places it costs much less, and there the cost of the gas is proportionately reduced.

Referring to our engravings, we may observe that the idea of gasworks is usually accompanied by that of the occupation of a large ground space. By the process under notice, however, the gas is made at about the rate at which it can be used, and there is consequently no need of a large holder, which is the main offender in the matter of ground space. But the Dowson Economic Gas Company, of 3 Great Queen Street, Westminster, have carried the matter a step nearer perfection by the introduction of their special compact plant, of which we give an elevation at Fig. 1 of our engravings and a part sectional plan at Fig. 2. This plant includes a combined scrubber and gas holder 6 feet diameter by 6 feet high, with a wrought iron tank for the same. The whole, with the generator, requires a ground space of only 10 feet by 7 feet, when the smallest generator is used, and about 10 feet by 8 feet, when the largest is used. Referring to the letters of reference on our illustrations, *a* is the steam producer and superheater; *b*, the injector; *c*, the gas generator; *d*, the chimney and waste pipe; *e*, the down pipe conveying the gas to the siphon box; *f* is the siphon box, and *g* the inlet pipe of the gas holder; *h*, the scrubber No. 1; *i*, *i*, the water spray pipes; *j*, the water supply pipe; *k*, the scrubber No. 2; *l*, the gasholder; *m*, the outlet pipe of the gasholder; and *n*, the steam and air escape valve. This special compact plant constitutes in itself without accessories or further expense a complete set of gas making apparatus. A governing arrangement is also supplied by means of which the production of gas can to a certain extent be regulated automatically to suit a varying rate of consumption. This plant has been specially designed for gas engine work; but it can also be used for any purpose for which a large storage of gas is unnecessary. For persons desiring to make their own gas on a moderate scale, the Dowson system presents several very satisfactory features. Thus, the production of gas being steady and continuous, there is no need of the large and expensive gas holder, inseparable from the intermittent processes. The latter, besides other drawbacks, requires skilled and anxious attention, owing to the necessity of reversing valves, etc., at frequent intervals, and this renders it impossible to obtain gas of uniform quality. With the Dowson apparatus, on the other hand, an intelligent laborer or stoker of the ordinary type is quite able to make the gas satisfactorily—the process being of an extremely simple, steady, and straightforward character. We may also mention another point of special interest. This gas is free from tar and ammonia; it cannot burn with a smoky flame; and there is no deposition of soot, even when the object to be heated is placed over or in the flame. These points are important for nearly all applications of gas, and especially in gas engines. They are also specially interesting to textile manufacturers, to whom the question of cleanliness and freedom from dirt and smoke is one of the highest importance.—*Iron.*

JAPANESE TECHNICAL APPARATUS.

IN the paper recently read before the Society of Arts by Mr. Henry Cunynghame, on Technical Education, prominence was given to the consideration of the means for providing instruction in physical science without costly apparatus, and the work of Professor Guthrie at South Kensington was referred to as an illustration of how it might be done. That ingenious people, the Japanese, have taken up the matter in a very practical way.

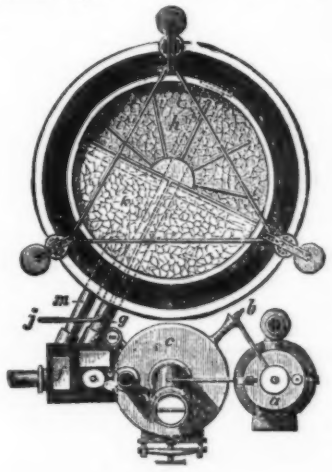


FIG. 2.

The great interest in the apparatus which Japan boys are taught to make, such as was lately shown in London, lies in the degree to which simplicity has been pushed, in the fertility of resource, and the ingenuity and skill displayed. Many a teacher in our elementary schools hesitates to take up the teaching of physics and chemistry, on the ground that the apparatus is so costly.

The Tokio school trains teachers to be sent to poor villages, where a collection of apparatus such as still in this country is regarded as a befitting equipment for a laboratory would be out of the question. Hence we see bamboo canes, corks, scraps of wire, old bottles, broken tools, flower pots, in short, things that in every village would go to the rubbish heap, utilized for the construction of apparatus. To those who have not seen in the South Kensington Museum what Professor Guthrie's pupils have done, it would appear almost

incredible what those Japan boys can do. They do not come up to the South Kensington work in point of finish and elegance, but this is not aimed at. To find the handiest material for doing just what is wanted is the point. No doubt the specimens exhibited in this country are picked, it is natural that should be so, still they are representative. What simpler material for the construction of an electric machine could be thought of than two old beer bottles, one for the cylinder and the other as an insulating stand, a fragment of an old saw, an old bell, some long sharp nails driven in a row, some old handles and other bits of wood? Or, again, for a mercurial air-pump, some short lengths of glass tubing, bottles, a tumbler, sealingwax, string, and caoutchouc? Yet, somewhat clumsy though it looks to our eyes, accustomed to delicate and finished instruments, it illustrates the manner of its acting, even if it should not be capable of working with great perfection. Then there is a simple polariscope, a Coulomb's torsion balance, and a Cartesian diver, consisting of an egg shell, a small stone, a bottle and cover. A model to illustrate the principle of an equatorial telescope is specially simple. It belongs to another section, but illustrates simplicity. Into the cork of a bottle is put a short piece of wire, on to which is placed another cork. From this springs another wire, on to which a soft wax candle is pushed. Why a bamboo cane is not used instead of a wax candle is not apparent, but the principle is the same.

For chemistry the arrangements are just as simple. A retort stand is made from bamboo, a piece of wire-work ash-sifter for the retort to rest on, and a strip of bent bamboo to form a clip. Where bamboo cane can be used instead of glass, it appears to be done; for example, in place of a glass jar with a nozzle for burning hydrogen, a large hollow cane, stopped at one end with a tobacco mouthpiece, is used. This, perhaps, is really hardly so simple though as the usual way of generating the hydrogen in the same bottle as that from which it was burned. Stoneware jars, however, seem in all cases used as retorts, for no glass retort is shown. Teachers often say they cannot show their pupils the decomposition of water; but here is a Buren battery (one "cell" at least), made of a glazed pot, a porous pot, a coil of zinc, and a stick of charcoal. The "collector" is equally home made, except that the two test tubes probably have to be purchased, and these are cheap enough; it is in the putting together the skill lies.

All the rest of the apparatus is equally simple, and all, as it is intended, within the reach of a young teacher going to settle down as schoolmaster in a poor village.

So far, cost only has been spoken of. There is another aspect of the subject, which applies to the study of physics and chemistry, in their earlier stages at least, not only in Japan, but everywhere. In more recondite researches, skilled and experienced manipulators are, without doubt, needed, but that does not affect normal schools. This other aspect is the effect of method of study on the student. When "the natural sciences" were first admitted into the curriculum of our universities, lectures were deemed sufficient. They dealt in generalizations without illustrations of the facts on which the generalizations were based. Then followed the introduction of experiments. But the experience of teachers was that the students might retain general impressions of some of the experiments, or possibly remember some exact wording in which some of the generalizations might be expressed. It was not till Professor Adolf Weinhold's "Vorschule der Experimental-physik" showed teachers how to arrange apparatus, "home made," for their classes, that the way of getting over the difficulty was made clear. Professor Carey Foster, in his preface to the English edition of this work (1874), wrote: "Hitherto, unless a teacher has been able not only to devise a general plan of instruction, but also to contrive every detail of experimental work, he has had no choice but to fall back on text-books. Now all who wish to adopt a more satisfactory system have a guide. This guide has been followed in England, and the principle of directing students how to devise their own apparatus is on the increase. Priestley, Dalton, Cavendish, Faraday, and other pioneers had to devise theirs, and they often had the homeliest materials. Skilled philosophical instrument makers are needed for delicate apparatus, but it was want of ingenuity that led students to go to them for what they could do themselves. The change has for some years set in, and Japan, in doing what she is, is acting in accordance with the experience of distinguished European teachers. The introduction of the method to Japan was due to two English professors.—*Journal Society of Arts.*

DIRECT PHOTO-TYPOGRAPHY AND PHOTO-LITHOGRAPHY BY THE CHROM-ALBUMEN PROCESS.

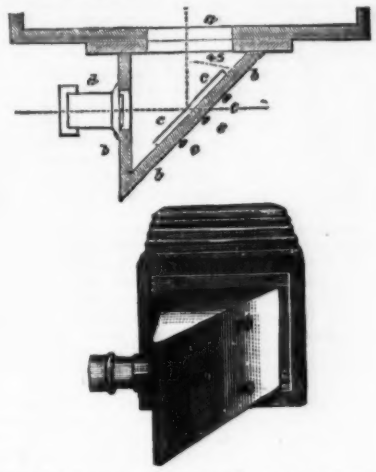
PROFESSOR J. HUSNIK has recently published full working details for the direct process on zinc, and the process not only gives us a ready means of reproducing the finest stipple or grain sketches with all their original characteristics, but it also saves the labor and delay of making the transfer and the delicate task of inking up the first image on the metal plate.

It is quite true that the asphalt process gives results equal in sharpness and quality to those obtained by the chrom-albumen method; but as the sensitiveness of the bitumen film is very slight in comparison with that of the bichromated albumen, the latter method has a decided advantage.

Any direct process on zinc requires the use of a reversed negative, and it is only necessary now to refer to the method of obtaining these by means of the prism or mirror, a proceeding to be recommended when the negatives are to be made specially for the work.

Mr. Romain Talbot's convenient arrangement for using the mirror is shown in the subjoined figures, the first cut showing the arrangement in section, and the second exhibiting the external appearance of the camera when fitted.

A circular mirror, *c c*, is mounted in the triangular box, and this mirror can be adjusted to the exact angle of 45° with the face of the camera by means of adjusting screws, of which the heads are shown on the outside of the box. Commercial plate glass is not sufficiently true on the face to be used for the mirror, unless one is exceptionally fortunate in finding an accurately surfaced piece; but it is necessary to obtain a true disk of glass from an optician. For silvering the glass, one cannot do better than to quote the directions for working Common's process.



"The solutions recommended by Mr. Common are three:

(1)	Nitrate of silver	1 ounce.
	Distilled water	10 ounces.
(2)	Caustic potash	1 ounce.
	Distilled water	10 ounces.
(3)	Glucose	½ ounce.
	Distilled water	10 ounces.

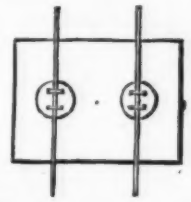
"The above quantities are sufficient for 250 square inches; consequently, an ordinary copying mirror 8x6 would require rather more than 2 ounces of each solution, and other sizes in proportion.

"The caustic potash and distilled water must be quite pure. Ordinary caustic potash will not answer at all. The best to use is known as *pure by alcohol.*

"The glass surface to be silvered is carefully cleaned with strong nitric acid, applied as recommended by Mr. Browning, with a Buckle's brush, then well washed in clean water, and, after rinsing with distilled water, laid, face downward, in a dish of distilled water till wanted.

"Before cleaning the glass, it will be necessary to arrange for supporting it face downward in the depositing dish, so that the surface to be silvered may be quite horizontal, and just below the level of the fluid, which should be about half an inch above the bottom of the dish.

"I have generally used a large cork, about four inches in diameter, cemented to the back of the plate, and fitted with three strings, by which it could be suspended in a level position and adjusted to any height by winding the string over a roller placed at a convenient height above the dish. As this arrangement was not available, I fixed on the back of the plate two ordinary wide-mouthed bottle corks of equal thickness in the positions shown in the figure, and to these corks attached thin slips of bamboo running transversely across the plate, and of sufficient length to rest on the sides of the dish, thus:



"The slips of bamboo gave the arrangement a certain amount of spring, by which the height of the plate could easily be regulated by putting on weights till the surface of the plate was just below the level of the fluid in the dish.

"To prepare the silvering solution. A sufficient quantity of the silver solution No. 1 (2 ounces) is put into a perfectly clean glass. Ammonia is dropped in till the precipitate first formed is just redissolved. The same quantity of potash solution No. 2 as of silver is now mixed in, and the precipitate again dissolved by ammonia. A little more silver solution is then added to produce a distinct turbidity, and distilled water to make up the quantity necessary to fill the depositing dish to about three-eighths or half an inch, and the mixture is then filtered through cotton into another clean glass vessel.

"The same quantity—two ounces—of filtered solution of glucose No. 3 as was taken of silver and potash is now mixed in, and the whole poured into a depositing dish (which should preferably be of glass well cleaned with nitric acid).

"The glass plate is then taken out of the distilled water, and laid face downward on the silvering solution, being supported—as before described—just above the surface, so that the solution does not cover its back.

"Mr. Common places the requisite quantity of distilled water in the dish, in which the mirror has been remaining face downward, and then, having lifted the mirror up, pours in the undiluted silvering solution, together with the glucose solution, stirs well together, and then carefully lowers the mirror again into the dish.

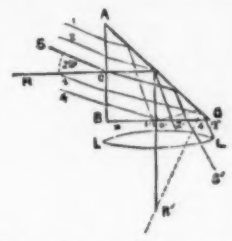
"Almost immediately after the immersion of the plate, the silvering action begins, and, if things are going on well, a brilliant reflecting surface will be seen at the back of the plate; and in forty minutes, or even less, a good deposit of silver will be obtained. It is usually recommended to stop the action as soon as the silvering fluid appears clear and free from turbidity; but it is not always easy, I find, to see this.

"After silvering, the plate is thoroughly well washed, finishing with distilled water, and dried off quickly. A slight cloudiness of the surface may appear, and must be removed by polishing before the mirror can be used. It is better to allow the mirror to remain a day or so before polishing, in order to harden the coating.

"To polish the plate, it should be slightly warmed, and perfectly dry, and rubbed very gently in small circles with a piece of very soft and dry chamois leather, afterward using a little jeweler's rouge.

"Mirrors should always be kept in a dry place, and will require repolishing from time to time."

Although, when the reflecting prism is used, the exposures are a trifle longer than in the case of the mirror at its best, the liability of the silvered surface to become tarnished is so great—especially in a crowded city—that much is to be said in favor of the prism. It must, however, be remembered that the reflecting prism is not suitable for use with wide-angle lenses. The following sketch sufficiently illustrates the action of the reversing prism, and it is usually mounted in a triangular brass box that fits on the external end of the lens mount.



To prepare the chrom-gelatine solution, dissolve thirty grains of ammonium bichromate in four ounces of distilled water, and after having added, drop by drop, sufficient liquid ammonia to make the orange color of the solution change to a bright yellow, the white of a fresh and tolerably large egg is added. When well mixed, the preparation is filtered through fine muslin, and afterward through filtering paper.

A plate of planished zinc, as sold at the lithographic material stores, is now carefully cleaned with the fine emery paper (No. 000) sold by dealers in watch-makers' materials, care being taken not to touch the clean surface of the metal with the hand. Strong ammonia solution is now poured upon the metal surface, and well rubbed on with a tuft of blotting-paper. The plate is now thoroughly rinsed under the tap, drained, placed on a leveling-stand, and the prepared surface is flooded with the chrom-albumen solution. The liquid must be allowed to flow in waves several times backward and forward on the plate, and some must be allowed to flow off at each corner of the plate. The operation of flooding and flowing off at each corner must be repeated. Now bring the plate into an upright position, in order to allow the superfluous fluid to drain off, wipe away the fluid which collects at the bottom edge, and by rocking the plate while held in a nearly horizontal position, diffuse the remaining liquid evenly. The plate is now gently and cautiously warmed over the flame of a spirit lamp, the plate being held at a very slight inclination, so that the upper edge dries first, and the liquid does not flow back on the portions just dried. At the same time, great care must be taken that the plate is not so much heated as to coagulate the albumen; but if the plate is not made so hot as to feel unpleasant to the back of the hand, there is no fear of coagulating the albumen.

When dry, the surface should be yellow and brilliant; if it is dull or matt, too much bichromate has been used, or the drying has been too slow. It is scarcely necessary to say that the work of coating and drying should be done in a room lighted with yellow light. The exposure required is merely a short one, less than the time necessary to make a print on albumenized paper; and after exposure it is necessary to ink the plate over with a very thin but uniform layer of printing ink, taking care that the roller is in good order, and not too heavily charged; after which the zinc plate is placed in cold water, and after having been allowed to soak for a few minutes, it is carefully mopped with a tuft of lint or cotton wool, this operation being continued until the whole of the subject is perfectly developed. In case of under-exposure, the lines wash off; and in case of over-exposure, it is difficult to clear the ground.

The plate is now etched into relief by the usual chemigraphic method.

It is scarcely necessary to say that this method is applicable to photo-lithography, it being merely necessary to take a transfer from the zinc.—*Photo. News.*

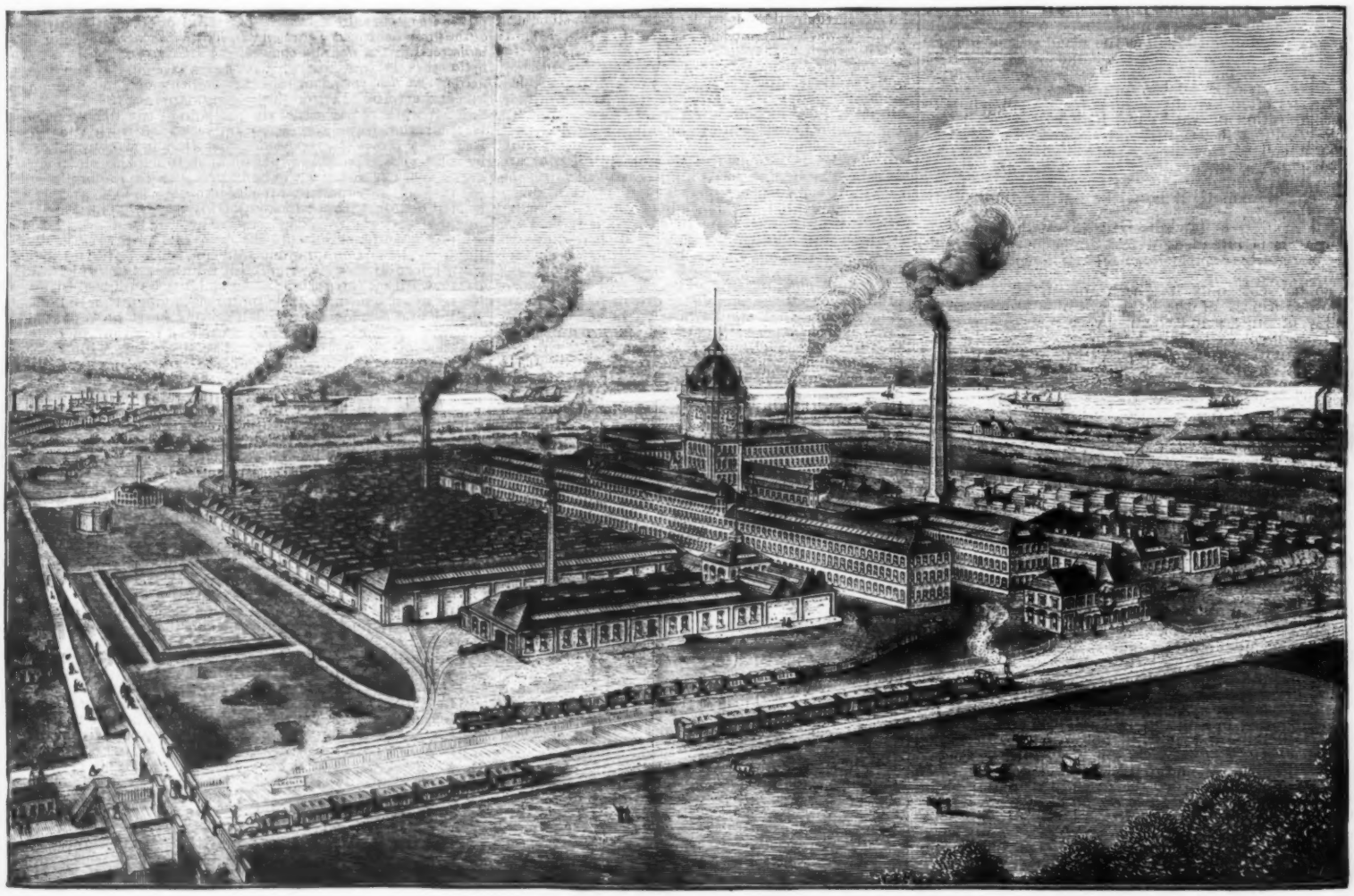
ESSENTIAL OILS.

AMONG the various devices for making the soil of England commercially profitable, the growing of flowers for the sake of the essential oils, though it can hardly become a great enterprise, deserves encouragement wherever success is possible. A considerable acreage of land at Grove, near Canterbury, has lately been planted with lavender and mint, and the result has proved so successful that it has been determined to establish extensive works on the spot, in order to carry on the process of extracting the essential oils. So far there is no reason to question the profitable outcome of the venture, though, of course, the demand for the oils of lavender and peppermint is more limited than for wheat or Kentish pippins. Still, they are used in more industries than people generally know of, and there is, moreover, this to be said for them, that if the market is not so great, neither is the competition for purchasers so keen. No discovery of the laboratory has ever yet managed to supply an ether which will replace the natural scents elaborated by nature in the cells of wild herbs. Nor can the cultivator of the plant yielding the precious oils contrive to so stimulate his crops that the products of one locality will fetch the same figure as those of a more favored region. It is not more hopeless, says the *Standard*, for the tobacco grower to Germany to pass the rank leaves which have matured under the Teutonic suns for real Havana, than it is for the flower farmer of one spot, seemingly as suitable as any other, to deceive the perfumer with the tale that the herbs have been nurtured in a soil the reputation of which stands in greater esteem. Curiously enough, it does not always follow that the lands of sunshine are always the best for this description of harvest. Thus, the shores of the Mediterranean, near Grasse and Nice, are the best localities for the

orange and mignonette, the perfection of the essential oils extracted from the flowers and leaves of these plants requiring low, warm, and sheltered spots. But the violet grows sweeter and sweeter as we ascend from the lowlands, and is most highly scented just as the foothills of the Alps are approached. Again, though France and other southern countries send us plenty of oil of peppermint and lavender, none of it can rival that grown at Mitcham in Surrey, almost a suburb of London, which is said to bring eight times the price of the foreign oils. It is thus clear that the Kentish flower farmers have some margin within which to work. Every year there is imported into this country between two hundred and three hundred thousand pounds weight of essential oils, the greater portion of which—leaving out of account cassia, vanilla, cloves, and lemon, which are scents of faraway lands—could just as easily, and a great deal more profitably, be produced within the bounds of the United Kingdom. Lavender, for example, has for centuries been grown at Hitchin, in Hertfordshire, and as a commercial speculation it dates back for at least sixty years. The plants at present in cultivation do not produce seed, being propagated by slips or by dividing the roots. The crop is, however, somewhat precarious. During the severe winter of 1860 many of the plants were killed, and of late years a peculiar fungus has so decimated them that the price of the oil has, in consequence, risen considerably. At Market Deeping, in Lincolnshire, where lavender was formerly grown, the business has been discontinued on that account. Hitchin, however, still harvests the crop of about fifty acres—a sandy loam with a calcareous substratum being regarded as the best soil for the purpose, while the most favorable position for the lavender plots is a sunny slope, which the fogs do not reach, and where light airs blow freely, but which is not so high as to be in peril of early frosts. At Mitcham, Carshalton, and Beddington, localities all near each other, about three hundred acres are still under lavender, and a considerable area under mint, though here, as elsewhere, for the reason mentioned, and other causes connected with the altered habits of the people, the culture is reported to be on the wane. At one time it was an important industry, and the Church tithes of the parishes in question were proportionately valuable. The lavender flowers are collected in August and taken direct to the still, when the turn-out of oil to a great extent depends on circumstances beyond the control of the farmer. If June and July have been bright, the result is satisfactory; but if there has been dull, wet weather during these months, only half as much oil will be expressed. The oil from the stems is ranker and less valuable than that from the flowers; consequently, the portion which first distills over is collected separately, that which appears after about an hour and a half bringing a lower price. Should the flowers be distilled separately, a finer oil is obtained. But as the extra labor demanded by the operation adds about ten shillings per lb. to the cost of the oil, it is not usually done, since the "fractional distillation" described effects nearly the same end. After three years, the oil—which has been mellowing up to that date—deteriorates, unless it is mixed with alcohol, or redistilled. In France, Piedmont, and especially in the vicinity of the villages of the Mont Ventoux district and those to the west of Montpellier, the collection and distillation of lavender is widely practiced; but the very best French oil does not approach in price that of the English article, and the cheapest varieties are made by distilling the entire plant. Some oil comes also from America. Near New York the plant is affirmed by Professor Johnston not to be very hardy, but in the neighborhood of Philadelphia it is grown in considerable quantities, chiefly for "sachets," or sweetscent bags, and for "laying up linen," a use for lavender which is, unhappily, not on the increase in this country. The *Lavandula spica*, which yields the "oil of spike," is a variety which cannot be grown in this country except in very sheltered situations, and is in any case inferior to that yielded by the common species. Peppermint culture requires no such nicety, and the distillation of the leaves is a very simple operation. The oil is still in good demand as a flavoring for lozenges, and as one of the drugs used in the pharmacopœia both as a stomachic and as a means of disguising the taste of other medicines. The cultivation of roses for the distillation of the precious attar would, in our uncertain climate, be a losing speculation, taking one season with another, though the profits for a fine crop are tempting enough to send some discouraged wheat growers into the business. The oil yielded by roses is very little; hence it is said that twenty thousand blossoms are required to yield a rupee weight of the "attar," which sells for 10*l.* sterling, a little fact which may suggest to the lady that the "real Oriental attar" which she bought in the Stamboul Bazaar for 10*s.* the ounce was not quite what the Moslem merchant so loudly swore by the Prophet it was. In reality, the true attar is almost invariably adulterated with sandalwood oil, or diluted with sweet salad oil, even in the Indian bazaars close to the far-famed rose gardens of Ghazepore. This seems almost pardonable when we remember that during unfavorable seasons it will take as many as 1,000 roses to yield two grains of the oil. In the forencon the red blossoms are collected by hand, and distilled into clay stills with twice their weight of water—the water which comes over being set to cool all night, and throwing up the thin film of oil which covers it in the morning like cream on new milk. This is the attar, which must be carefully swept off with a feather, and transferred to a small phial. After repeating this operation night after night, and morning after morning, nearly the whole of the oil has been extracted, the little which it is impossible to separate so flavoring the liquid that it is sold as "rose water," just as the minute particles left in the course of distilling lavender or peppermint are known as the "waters" of their essences. It is also quite out of our power in England to compete with the South for the production of jasmine oil, which is almost as costly as attar of roses, the "neroli," which is obtained from orange flowers, or the *petit grain* extracted from its leaves. But there is no reason why the anise, the caraway, and the iris should not be more grown for the purposes indicated, nor why the rosemary and the juniper should not be pressed into the service of the perfumer by the hands of the English agriculturist. At present, attar of roses reaches this country mainly from Smyrna and Constantinople, the oil of lemons from Sicily and Portugal, bergamot from Sicily, anise from Germany and the East Indies, and oil of cloves to a small extent from the Malay Islands, though it is believed that a large amount is distilled by the London whosesale druggists. Caraway is, however, still mainly a home product, and should the experiment pronounced so successful in East Kent be extensively followed, the not inconsiderable quantity of oil and lavender and oil of peppermint distilled in England is likely to be largely increased.—*Oil and Colorman's Journal.*

A NEW SINGER SEWING MACHINE FACTORY.

A FEW particulars of the gigantic new factory of the Singer Manufacturing Company, situated at Kilbowie, near Glasgow, on the banks of the Clyde, which has just been completed, may prove interesting to our readers. The growth of the business of the company was so rapid, largely owing to the "hire and purchase system" introduced by them, that their old premises at Bridgeton, a suburb of Glasgow, became too limited, and in May, 1882, Mr. G R. Mackenzie, of New York, president of the company, cut the first sod in the formation of the new works. The total floorage is more than 18 acres, there are upwards of 3,000 windows and 20,000,000 of bricks, 5,000 tons of cement have been employed in its construction. The main buildings are two parallel blocks 800 ft. long, 50 ft. wide, and having three connecting wings 75 ft. long and 50 ft. wide. This block has a total floorage of 273,750 ft., and is throughout of three stories, except in the center frontage, where an additional story has been added. The columns and beams are formed of rolled joists, and the flooring has been laid as follows: First, a layer of slag, on which is spread a coat of asphalt from 2 in. to 3 in. thick; over the asphalt, wooden sleepers about 12 in. broad are laid, and a double wooden flooring laid transversely,



THE NEW FACTORY OF THE SINGER SEWING MACHINE COMPANY.

makes a firm foundation for the various machines which are used in the manufacture of the sewing machines. Round the parallel main erection all the other departments are clustered. Adjoining the railway on the eastern side is the boiler shop 300 ft. long by 100 ft. broad.

The foundry, which lies immediately to the south of the boiler shop is the most extensive department of the works, being 445 ft. long by 365 ft. broad, having a clear space of four acres. Further to the south is the foundry store and annealing department 200 ft. long by 110 ft. broad. Attached to the annealing department are the premises for making, japanning, and ornamenting the stands, and adjoining is the room for shipping and storing machines. This immediately borders the Forth and Clyde Canal, so that the eastern block stretches from the railway to the canal. On the west side of the main building is the smiths' shop, 220 ft. long and 169 ft. wide. The japanning department is 276 ft. long, 104 ft. wide, and is of two stories. The cabinet and box making department is a square, inclosing a courtyard 355 ft. long and 178 ft. wide. The whole of the buildings are made of brick, and the two main erections are connected in the center by a massive square clock tower, 200 ft. high and 50 ft. diameter, from which a fine view is obtainable.

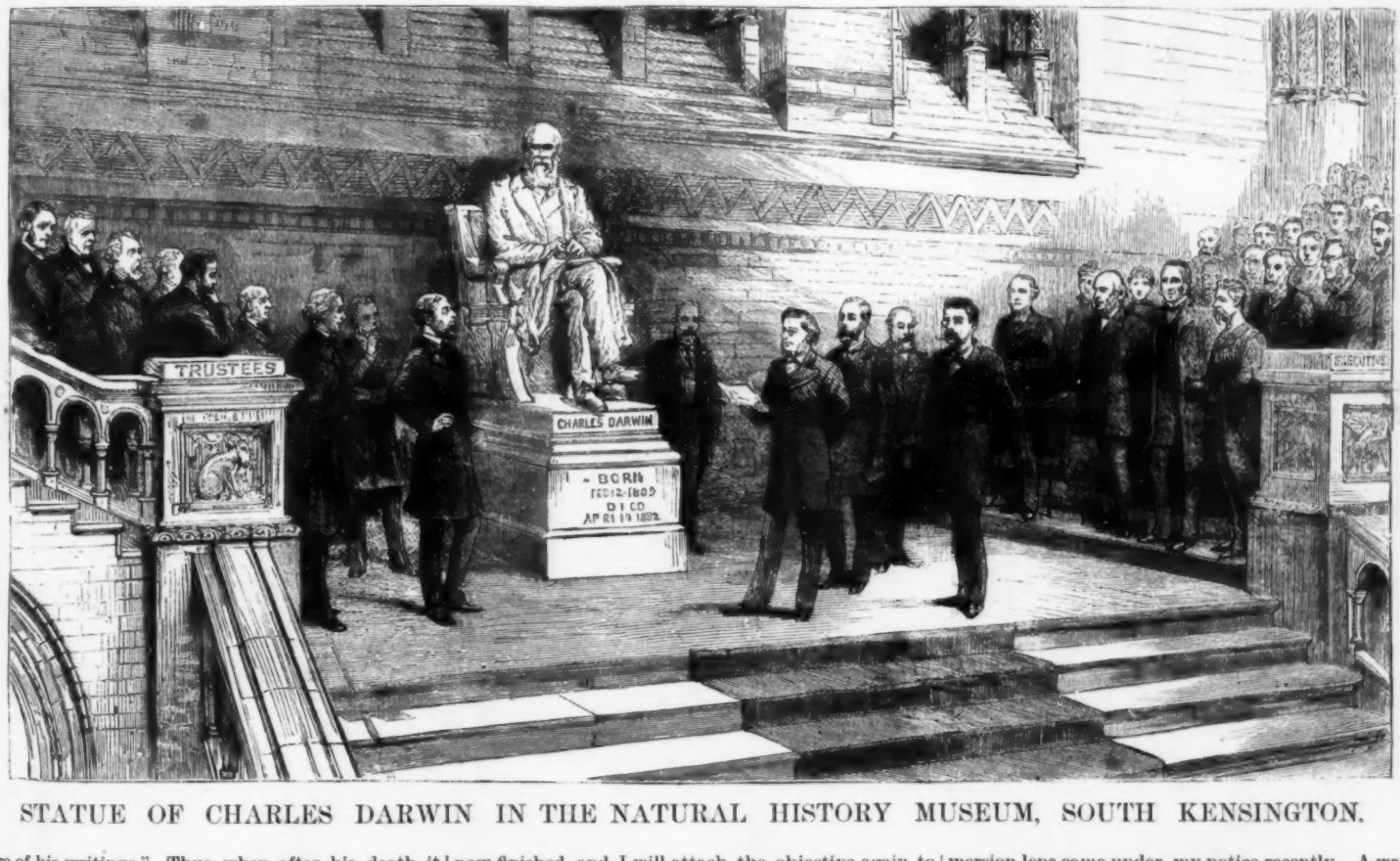
The extensive machinery is of the latest construction, and all the tools used in the manufactory are made by the company themselves. The needle making machinery is perfectly unique, and it may be here remarked that during last year upwards of 20,000,000 needles were produced. By an arrangement of fans the shavings, chips and dust are all drawn off into chutes

which carry them outside the buildings. At present the works employ 3,000 hands on full time, and when they are in full operation they will be capable of producing 6,000 machines weekly. The buildings were designed by and erected under the superintendence of Mr. Robert Ewan, architect, Glasgow, who has carried on the work most successfully.

UNVEILING THE DARWIN STATUE.

ON June 9, 1885, the Prince of Wales formally accepted on behalf of the Trustees of the British Museum, and for the nation, a statue of Charles Darwin, which, as the London *Times* aptly remarked, "forms the visible representation of the recognition by the civilized people of the world of the value of the life work of this patient observer, fearless thinker, and judicious writer."

The statue, which has been executed by Mr. Boehm, R.A., is of white marble, and has been placed on the top of the first flight of steps facing the entrance hall. A large gathering of scientific and literary men assembled to witness the unveiling, and on either side of the statue stood the Prince of Wales and Professor Huxley, President of the Royal Society—the only two speakers on the occasion. Professor Huxley spoke first, and dwelt upon the manifestation of public feeling called forth by the great scientist's death, "not only in these realms, but throughout the civilized world, which, if I mistake not, is without precedent in the modest annals of scientific biography." Proceeding to speak of the great work achieved by Darwin, whose "Origin of Species" completely changed the "fundamental conceptions and the aims of the students of living nature," he then passed on to the manner in which, after barely twenty years of controversy, the importance of Mr. Darwin's labors had not only been fully recognized, "but the world had discerned the simple, earnest, generous character of the man that shone through every page of his writings." Thus, when after his death it was proposed to raise a fund for erecting a statue, contributions flowed in from all parts of the world, and from all classes of the community. To mention one interesting case, Sweden sent in 2,296 subscriptions "from all sorts of people," as the distinguished man of science who transmitted them wrote, "from the bishop to the seamstress, and in sums from 5*l.* to 2*d.*" The committee have thus been enabled to carry out the whole of their scheme, and not only to erect a handsome statue, but to create a Darwin fund to be held in trust by the Royal Society, to be employed in the promotion of biological research. On the statue being uncovered, Professor Huxley in another speech asked the Prince to accept the gift on behalf of the Trustees of the British Museum; and the Prince made a suitable reply, declaring that the Trustees in accepting the statue had "willingly assigned this honorable place to the statue of this great Englishman, who has exercised so vast an influence upon the progress of those branches of natural knowledge which is the object of the vast collection gathered here. A memorial to which all nations and all classes of society have contributed cannot be more fitly lodged than in our museum, which, though national, is open to all the world, and the resources of which are at the disposal of every student of nature, whatever his condition or his country, who enters our doors." On the pedestal of the statue is inscribed: "Charles Darwin, born February 12, 1809; died April 19, 1882."—*The Graphic.*



STATUE OF CHARLES DARWIN IN THE NATURAL HISTORY MUSEUM, SOUTH KENSINGTON.

THE longer I live, the more certain I am that the great difference between men, the feeble and the powerful, the great and the insignificant, is energy and invincible detetmination, a purpose once fixed, and then death or victory. That quality will do anything that can be done in this world; and no talents, no circumstances, no opportunities, will make a two-legged creature a man without it.—*Sir T. Fowell Buxton.*

CARE AND USE OF MICROSCOPE LENSES.*

By WILLIAM WALES.

HOWEVER good the lenses of an instrument may be, they will not do their best work except when properly cared for and properly used. Yet I have met with reputable microscopists who do not in practice appreciate this obvious truth. Let me show you how a lens is cleaned. My implements are four—an old, soft, silk handkerchief, a small stick of soft wood, a phial of alcohol, and a watch maker's glass of two powers. I have here an eye piece. I will first examine it with the magnifying glass, by reflected light, to learn its condition. If it be found to need cleaning, alcohol is to be applied with the handkerchief. This liquid must not be allowed to touch the lacquer; but the cell which holds the lens will not be harmed by it, since that has been burned black with acid. If, after the cleaning, fibers from the cloth be found adhering to the lens, they may be blown off by a quick breath.

I have brought an objective which was sent to me to be cleaned. I will attach it to an instrument, and will place under it a slide of familiar diatoms. Now view the object through the lens. It looks so obscure that you will all exclaim, "Well, this is a very poor objective;" whereas it is of excellent quality, as you shall presently see. In it are eight pieces of glass. The back combination is composed of two crowns and the flint; the middle, of a double concave flint and a double convex crown; the front, of two crowns, with a flint between them. It has, probably, not been cleaned for twenty years. Suppose your watch to have been thus neglected! I will now clean this objective. I begin the work by unscrewing the cells. I then moisten a part of the handkerchief with alcohol, and with the help, if needed, of the stick of wood in searching the corners carefully clean each combination, and I then screw each cell back accurately to its place. The work is now finished, and I will attach the objective again to the microscope, and will again ask you to view the slide of diatoms through it. The dimness is now, you perceive, all gone. Indeed, you can hardly believe it the same objective, and you have ocular proof that cleanliness is essential to the best performance of a lens, and are witnessing an instance of the dependence of important results on attention to little things.

Several years ago, while I was getting ready to visit England, the owner of a Powell and Lealand objective wished me to take the lens to its makers for correction or exchange. "It is a poor lens," he said. I could not credit his statement, for I knew the work of the Messrs. Powell and Lealand to be faultless. I called on those gentlemen. We examined the objective together, and discovered on one of the combinations a film of some substance which could not be removed except with alcohol. In five minutes the lens was clean and in perfect order; and to this day the owner refuses to believe that the lens which I brought back to him is the same that I took abroad. Never trust the cleaning of your objectives to the brass worker, or to any person who does not know how carefully a lens ought to be handled. The brass worker will polish the outside of the objective, but will get the lenses out of center. To my great disgust, I once found a brass worker subjecting one of my 4-10 inch lenses to that treatment. I asked, "What are you doing with that objective?" "Putting it in order at the request of its owner," he said; "he wants to sell it." Taking the lens, I cleaned it for him without charge. A camel's hair brush can neither completely nor safely remove the film of dust with which the exposed surface of the back combination of an objective is sometimes found to be coated. It will make a series of rings on the surface of the lens, and it may, if grit be present, scratch the glass. Nor should the handkerchief, either wet or dry, be introduced into the tube of any but a low power objective. The cells must first be unscrewed from their mountings, and then the cleaning be done properly. But, let me add, an objective ought never to be taken apart by any one but its maker. He has the lathe upon which it was made, and he alone, when the parts have been separated, can replace them in their original adjustment to the optical center. Any other person will be likely to screw in the cells either too tightly or not tightly enough, and will thus throw the combinations out of their necessary delicate relation to one another. Besides, unless skill and care be exercised in screwing the parts together, the front and the middle combinations will sometimes be brought in contact, and the flint glass, which is very thin at the center, will be broken. The screw thread of the cells is very delicate. Yet some persons, after failing to catch it, apply force enough to break it. Such carelessness passes comprehension.

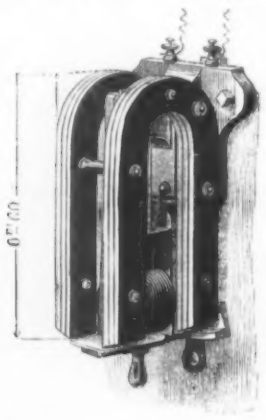
A large angle oil-immersion lens gets out of order easily. If you find the definition of such objective to have lost its sharpness, you may know that the front lens is out of center. It has come in contact with the slide. A very slight pressure is sufficient to work the mischief. This susceptibility to injury is unavoidable, as every optician will tell you. It is incident to the requirements of high angle construction. A few days ago an objective was sent to me with the request that the front lens should be reset. It had in some way been forced out of its place. I reset it as well as I could. But that objective, even if it had been repaired by its makers, the Messrs. Powell and Lealand, can never be what it was before the injury. The only way of repairing it was by inserting a ring of cement, which, projecting slightly through the shoulder, necessarily cut down the angle. A heavy shoulder means, of course, a low angular aperture. A novel method of using an immersion lens came under my notice recently. A water immersion objective had been ordered. It was made and sent, but it did not give satisfaction. I inquired by letter, "In what way do you proceed to work with it?" "I fill it with distilled water, and then screw it to the instrument," was the reply. An objective is sometimes almost ruined through sheer carelessness. I made a costly lens for a New York optician. He tossed it several times in his hand, and finally dropped it upon the floor. "Oh," he said, "that will not harm it!" I looked at it, and found the front combination tilted at an angle of about 45°. This act of carelessness cost that optician twenty-five dollars.

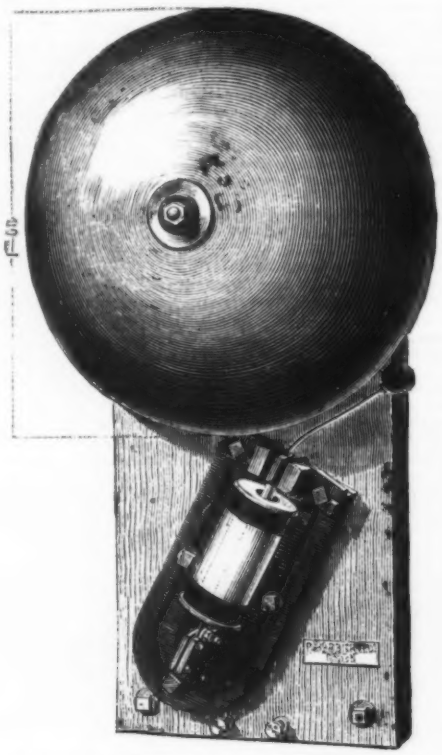
I have here the back setting of a 1¼ in. lens which was made by me several years ago. The purchaser of the lens had screwed it so tightly to his microscope that he could not, with his hand, unscrew it. So he used a pair of heavy gas fitter's pliers, and succeeded in pulling the tube of the fine adjustment out of the body of the instrument. This rude handling damaged the microscope to the amount of forty-five dollars. Quite recently the owner of an instrument which cost three hundred and fifty dollars told me that he had a wonderfully clever son. "Why," he exclaimed, "he has, with a screw driver, taken the microscope all apart! He is unable, however, to put it together again." This outrage illustrates the incapacity of some people, old as well as young, to appreciate the products of fine workmanship. I do not favor the nosepiece. If you must have one, choose one that is of good design and thoroughly well made. Lenses, especially those of high power, ought not to be tested with the use of this accessory. A superior lens, worked by an illustrious microscopist, becomes its maker's best advertisement. But when it falls into the hands of a careless or incompetent person, and is not carefully used or regularly and properly cleaned, to hold the maker responsible for its consequent unsatisfactory performance is to do him great wrong.

* A paper read before the New York Microscopical Society.

A NEW SYSTEM OF TELEPHONIC COMMUNICATION.*

ASIDE from domestic electricity, the domain of the application of calls is very wide. On railroads, for example, there is employed a very large number of the most diverse kinds that may be advantageously replaced by electro-magnetic ones. The system is, among other things, particularly well adapted to those large gongs which announce the departure of trains. Bells of these dimensions cannot be constructed after the pattern of ordinary pile bells. Beyond a certain size their operation becomes costly, and for actuating large gongs recourse is often had to clockwork movements that electricity only serves to throw into and out of gear. The electro-magnetic system, on the contrary, is admirably adapted to this sort of application—it being only necessary to enlarge the transmitter and receiver in order to obtain excellent results. It is well to remark here that as soon as the dimensions of the call are enlarged in a certain measure, there is no longer any need of thinking about the distance to which it is desired to transmit the signal. Experiment shows, in fact, that with a medium model the currents, without perceptible weakening, traverse 33 feet of arsenical copper wire (Mouchel's) $\frac{1}{2\cdot5\cdot5}$ of an inch in diameter, which represents a resistance of 30,000 ohms.





FIGS. 21 AND 22.—MAGNETIC TRANSMITTER AND RECEIVER FOR RAILROADS.

Figs. 21 and 22 represent the form of the apparatus for this new use. Fig. 23 shows the application of the magnetic call to a railroad station, and allows the size of the apparatus to be seen. We may add that the application of these new apparatus will not be limited to railroads. They may be used with advantage upon ships, for communicating between fore and aft; in large shops and in colleges for giving the signal of entrance and exit; in fire-engine houses; in theaters, for announcing the rising of the curtain; for church bells, and in many other cases still.

These calls present still one other advantage, and that is that they permit of the use of several receivers in tension in the same circuit. It is possible, for example, to operate twenty or more small-sized calls perfectly by means of one of the same model, and an unlimited number with a sufficiently large transmitter. This arrangement is very convenient for transmitting a signal simultaneously to several different places. In a hotel, for example, it will be possible to notify all the rooms at once of the breaking out of a fire.

When these magnetic calls had once been rendered practical for the different applications of ordinary signals, Dr. Herz undertook the second and most important part of the problem—the combination of the calls with magnetic telephones so as to do away with the pile in telephony. In doing this he was merely carrying out an idea that had always been in his mind, and the accuracy of which will escape no one who has occupied himself with telephony.

We know, in fact, that it is especially in this branch of electrical applications that the pile presents a great

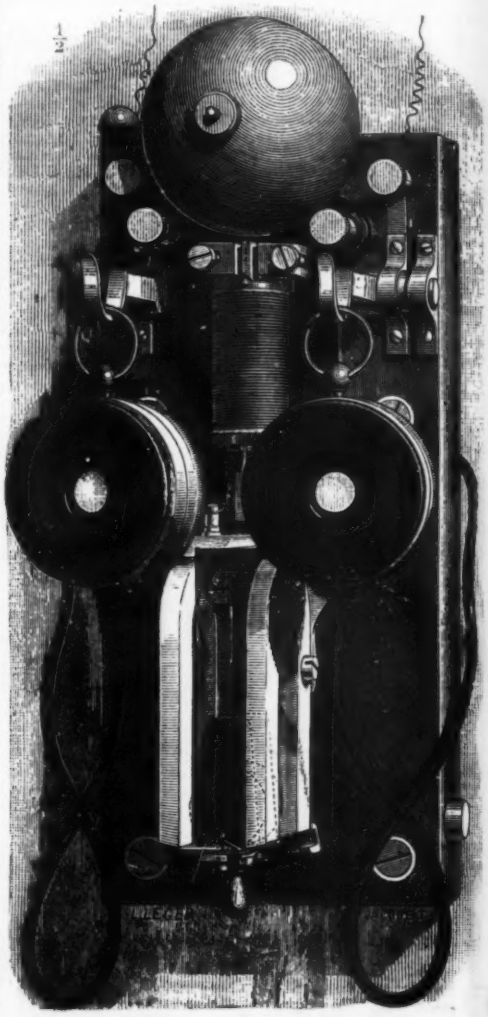


FIG. 24.—TELEPHONE APPARATUS WITH MAGNETIC CALL.

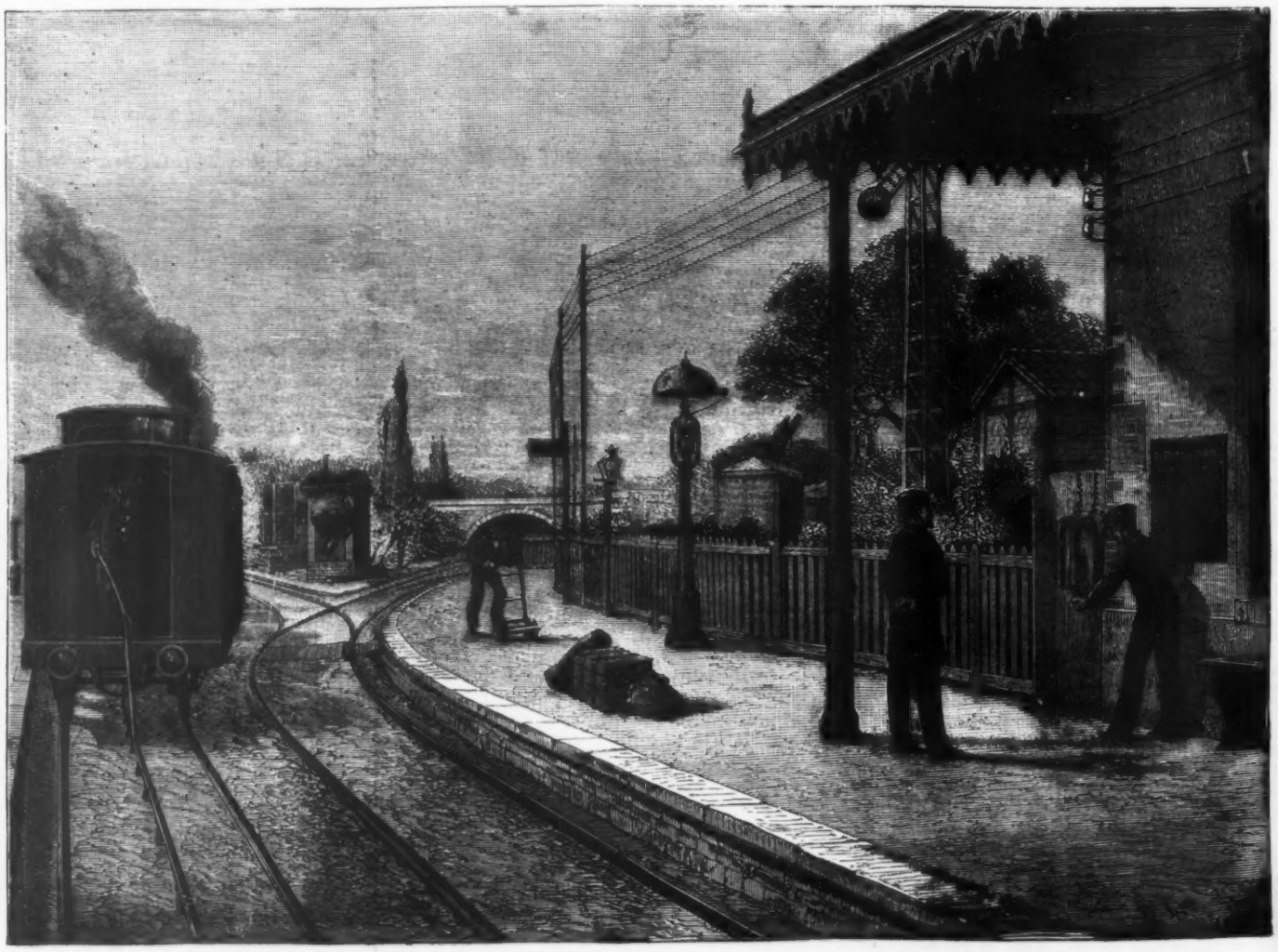


FIG. 23.—APPLICATION OF MAGNETIC SIGNALS TO RAILROADS.

* Continued from SUPPLEMENT No. 500, page 7983.

inconvenience. The microphone greatly weakens the Leclanche pile, and the batteries placed in the houses of subscribers need to be often changed. This inconvenience is so great that in certain places (Berlin, for example) the use of microphones by subscribers has

FIG. 25.

been done away with, and Siemens' magnetic telephones been substituted for them, the pile being merely retained for the bells and for the transmitters of central offices in order to lessen the fatigue of the employes.

In the face of such antecedents, and being given the new elements that one was in possession of, how to

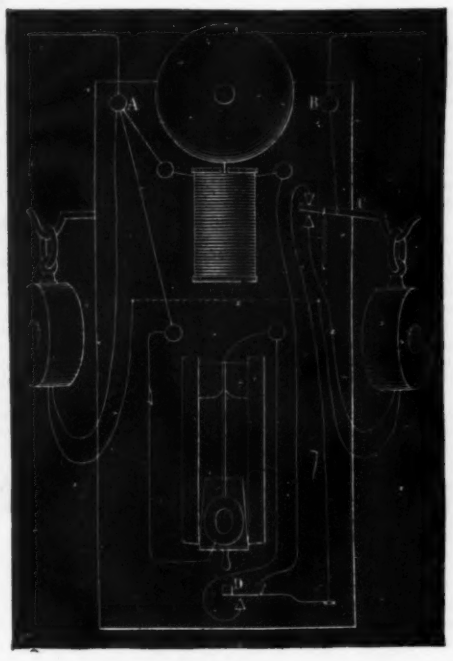


FIG. 26

combine different telephonic apparatus composed solely of magnetic calls and telephones was the problem which presented itself, and which was attacked without delay. Fig. 24 represents one of the first apparatus constructed. The arrangement adopted was, as may be seen, of the simplest nature. The call and the bell were fixed one above the other upon a vertical board, and the watch-shaped telephones were suspended on each side from hooks, one of which did duty as a commutator.

In a combination of apparatus of this kind the conditions to be fulfilled are the following: (1) in a position of waiting it is necessary that the current coming from the line shall traverse the bell alone; (2) when a station calls, it is necessary that the current sent into the line by its transmitter shall traverse neither its bells nor its telephones; and (3) when conversation has been established between the two stations, only the line and the telephones should be in circuit.

These three conditions are satisfied by means of two commutators placed at each station. The diagram in Fig. 4 shows what are then the communications between the different parts of the station. Let A and B be the two points of the line between which the apparatus is placed. The bell, S, the call, M, and the telephones, TT, will all be connected with one of these points, A. On the other side, the bell and call will end at a commutator, D. Then the exit wire of this latter and that of the telephones will reach a second commutator whose handle will be connected with B. It is easy to see what will occur according to the position given the commutator: If the two handles are in their upper position, the line current will traverse the bell only; if C remains in the upper position, while D proceeds to rest upon its lower contact, the call alone will be connected with the line; if C is upon its lower contact, the telephones, whatever be the position of D, will alone be in circuit with the line.

In the apparatus represented in Fig. 24, and of which Fig. 26 gives the commutations, the commutator, C, is formed by the hook of the telephone to the right. It preserves its upper position as long as the telephone remains suspended from it. The commutator, D, is represented by a button at the side of the board. It is a spring commutator, which is naturally in a position corresponding to the upper contact of the diagram. In a state of rest the two commutators, then, put the bell alone into the circuit. When it is desired to ring, one hand is placed upon the button, which depresses D, and, with the other, the cell, which is then in line, is maneuvered. Finally, when the telephone is unhooked for speaking, C is depressed by its counter-spring, and the telephones alone remain in circuit.

This arrangement, while answering the object proposed, still presented one drawback, and that was that, at the moment of calling, both hands had to be used. So an endeavor was soon made to substitute for the play of the button, D, an automatic commutator actuated by the call itself. Several arrangements were devised for this, and one of these we shall describe.

In front of the spring, R, of the bobbin (Fig. 27), there is fixed a piece of wood, H, which carries two pairs of springs—one, L L, anterior, and the other, F F, posterior. The latter are connected with each other at the upper part, press strongly against the piece, H, and take its form. Thanks to this arrangement, they are constantly under tension, and this prevents them from vibrating during the operation of the apparatus. Their vibration, in fact, would produce interruptions of the current that would weaken its action upon the bell.

The lower extremities of these springs are in close proximity to the metallic projection, P, soldered to the anterior cheek of the bobbin; but they do not touch it in a normal state. The springs, L L, bear against a metal plug, E, which traverses H and sets up a communication between them. Their extremities face an insulated part of the projection, P. As may be seen in Fig. 28, in a state of rest the springs, F F, which are connected with the line through the intermedium of the commutator, C, do not give any contact; but the springs, L L, and the piece, E, connect the bell with the upper contact, C, so that the current coming from the line can traverse the bell only. When, on the contrary, the bobbin is moved, the insulating part of P (Fig. 27), separating the springs, L L, by turns, allows no communication to exist with the bell; but the metallic part of P, being always in contact with one or the other of the springs, F, sends the current to C, and from thence into the line. The play of the commuta-

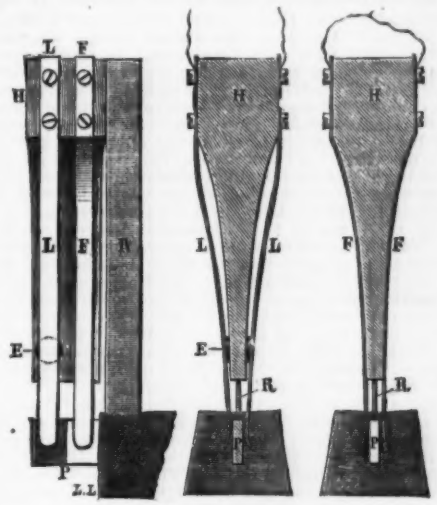


FIG. 27.

FIG. 28.

tor, C, remains the same as before. Thus improved, the apparatus shown in Fig. 24 may be considered as *the* type of domestic telephony.

It is simple and easy of management, and can give rise to no error in manipulation. As there are no longer any connections to make with a pile, its installation is

FIGS. 30 AND 31.—MAGNETIC CALL AND MICROPHONE TRANSMITTER.

limited to connecting the two apparatus with the two line wires, which is something that can be done by anybody whatever. Finally, the two telephones connected with each apparatus are of exceedingly easy management, and their range is more than sufficient for ordinary distances. The range of the magnetic call is, as we have said, very great. In some experiments performed between Paris and Creil, a distance of 30 miles, the bell operated as well as it would have done merely between two rooms of the same house. But the same would not be the case with the small watch telephones employed in the apparatus that we have described, and hence arose the necessity of constructing apparatus in which, while these handy little telephones should be retained, one might have at his disposal for transmission a more powerful magnetic telephone. One of these apparatus is shown in Fig. 28. The call and bell are here inclosed in a box which serves as a support for the three telephones. The transmitter is mounted with hard friction upon an axis which permits of giving it the most convenient inclination for receiving the sounds. The communications are the same as above described. The adjusted telephone is placed in a derived circuit between A and the lower contact of C (see Fig. 25). This apparatus, on being experimented with between Baron Rothschild's castle at Ferrieres and Rue Laffitte (Paris), a distance of 23 miles, gave the most satisfactory results. A magnetic call and microphone transmitter have been constructed after the same model. This apparatus is represented in Figs. 30 and 31. The microphone is of the Hughes system, and each apparatus is provided

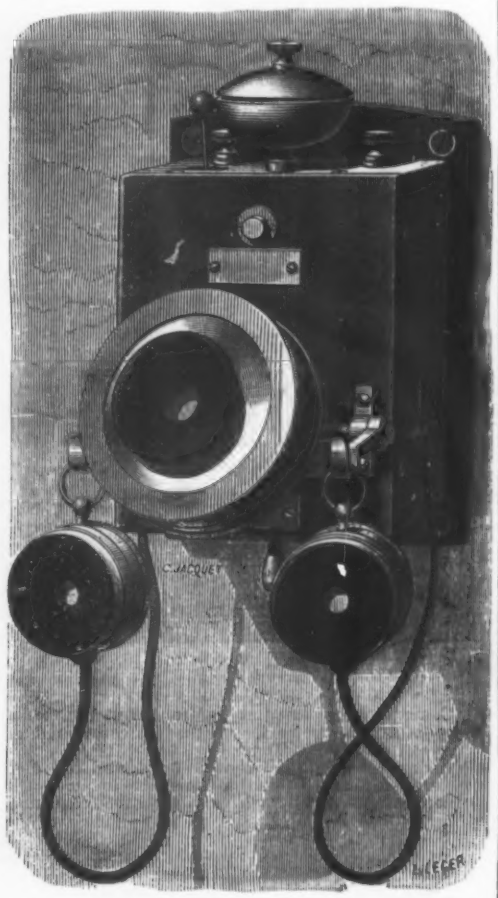


FIG. 29.—LONG DISTANCE MAGNETIC TELEPHONE.

with two Lalande & Chaperon elements fixed to the inside of the box. This apparatus possesses very great sensitiveness.

Fig. 30 gives an external view of the complete apparatus, and Fig. 31 shows its internal arrangement. As may be seen, it combines within itself the advantages of magnetic and microphonic apparatus.

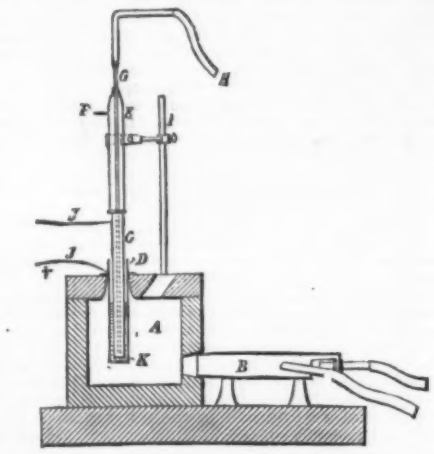
KENDALL'S ELECTRIC GENERATOR.

AT the International Inventions Exhibition, Mr. J. A. Kendall, of North Ormsby, Middlesbrough, exhibits an electric battery, which appears to be a decided step in the direction of producing electricity from the oxidation of coal without the intervention of a steam engine. The battery is based upon the well-known phenomenon of hydrogen passing through platinum at a red heat, two platinum plates being used as the poles, one exposed to hydrogen and the other to oxygen. These plates are arranged in the form of concentric tubes closed at one end, and are separated by a fluid medium of fused glass.

Hydrogen gas is continuously supplied to the inner platinum tube, while the entire apparatus is maintained at a high temperature by means of a furnace fed with coke or liquid or gaseous fuel. The absorption of hydrogen by the platinum is accompanied by electric generation, and the current is led away by wires connected to the platinum tubes. It is curious, however, that so long as the two platinum tubes are not connected by a metallic circuit, the passage of the hydrogen is slow; but that as soon as the electric circuit is completed the rate of flow is suddenly increased, and is steadily maintained at the higher amount. The speed at which the hydrogen will pass in a single cell may be gathered from the following experiment:

A platinum tube, K, 2¾ in. long and ⅜ in. in diameter, closed at one end, was soldered to a strong iron tube, E, and fixed vertically. The platinum tube was immersed for 2¼ in. in fused glass contained in a platinum cell, D. This latter was 2¾ in. deep and 1 in. in diameter. The two platinum tubes were connected by platinum wires, J, with the galvanometer, and the iron tube was connected with a Sprengel pump, H. The cell being heated to bright redness in an oxidizing flame, a good vacuum was produced by the Sprengel pump. Then, while no bubbles of gas came down the fall tube of the pump, the galvanometer showed no deflection. The cell was then heated by a reducing flame. The galvanometer soon gave a steady deflection of 15 deg., and bubbles of hydrogen came down the fall tube of the pump. The experiment was continued for half an hour, and during 15 minutes the hydrogen coming down the fall tube was collected. It measured 1·33 cubic centim. When several cells are used in series, better results are obtained.

The accompanying figure illustrates a single cell of



the battery, and will be understood from the reference letters appended.

In the case of a group of cells or battery, the same gas furnace may be used to heat the series. The cells are connected for quantity and intensity as in the voltaic battery. The electromotive force of a cell is given by Mr. Kendall as about 0·7 volt. This is, of course, much less than the theoretical electromotive force of a hydrogen and oxygen couple, and the remaining energy evolved by the combination appears to be developed in the form of heat at the surface of the oxygen plate, and serves to keep up the temperature of the apparatus. At the Inventions Exhibition a grouped cell or battery is shown, together with specimens of the parts used in its construction.

In the action of the battery the hydrogen in passing through the inner tube, K, is, so to speak, filtered off from any gases with which it may be mixed, so that it is not necessary to use pure hydrogen. The residual combustible gases, if any, when drawn off by the escape jet, F, can be utilized as fuel for the furnace. This is a very valuable feature, as it enables the battery to be worked with strong producer gas, consisting mainly of hydrogen and carbonic oxide, and to be arranged in a very compact way, the spare heat left from heating the cells being available for working the producer.

Mr. Kendall proposes to employ it for a variety of purposes, for example, the driving of electric launches and so on. Voltaic batteries which consume zinc are known to be comparatively expensive as a rule; while the ordinary accumulators require recharging periodically.

With the new generator all that is required to maintain the working is a supply of fuel and a little water. The inventor estimates that a ton of coke used in heating the battery, including the hydrogen producer, will give at least three times the electrical energy which would be produced by the same quantity of coke used in working a steam engine and dynamo.

It is also hoped by the inventor to develop the new process of electric generation for lighting purposes. Houses can in this way be lighted by incandescent lamps by means of coal gas supplied to the premises; and larger centers of illumination could be economically worked by the use of ordinary fuel, such as coal and coke.—*Engineering.*

[Continued from SUPPLEMENT, No. 500, page 7978.]

[JOURNAL OF THE SOCIETY OF ARTS.]

ON THE CONVERSION OF HEAT INTO USEFUL WORK.*

By WILLIAM ANDERSON, M.Inst.C.E.

LECTURE IV.

IN my last lecture, I explained the great principle first laid down by Sadi Carnot in 1824, that in a heat engine the effect depends solely and entirely upon the fall of temperature caused by the external work done by the working substance, and not in any way on the nature of the substance, its absolute temperature, or on the mode in which it was heated or cooled. We know by experience that if we desire to heat a body, we must bring it into relations with some body hotter than itself, and then the more energetic molecular motion of the hotter body will gradually be transferred to the colder one, until an equality is attained.

Now, what is true of the transfer of invisible molecular motion from one body to another is equally true of the transfer of the invisible molecular motion of heat, and its change into the coarser and apparent motion of mechanical work. If an insulated hot body is doing external work, its temperature must fall, just as the swing of the single ball in the ball frame which I have exhibited here is reduced by transfer of its energy to the other balls.

The law of Carnot is, therefore, universal, that where a hot body does external work, a corresponding quantity of heat disappears as heat, and the amount of work done is in proportion to the fall of temperature, because the quantity of heat contained by the working substance varies as the temperature.

The laws of Carnot, as stated by himself, are the following:

1. The motive power of heat is independent of the agents employed to develop it, and its quantity is determined solely by the temperatures of the bodies between which the final transfer of caloric takes place.

2. The temperature of the agent must, in the first instance, be raised to the highest degree possible, in order to obtain a great fall of caloric, and, as a consequence, a large production of motive power.

3. For the same reason, the cooling of the agent must be carried to as low a degree as possible.

4. Matters must be so arranged that the passage of the elastic agent from the higher to the lower temperature must be due to an increase of volume, that is to say, the cooling of the agent must be caused by its rarefaction.

The last part of the fourth law should read, "the cooling of the agent must be caused by the external work it performs." Carnot was ignorant of the cause of the fall of temperature of gases expanding and doing work, and he held the emission theory of heat. Our admiration for the clearness of his views is greatly heightened by the consideration of the limited knowledge available in his time.

The sources of heat on the surface of the earth are numerous, and in their application they give out the heat potential in them in various forms, such as heat, light, electricity, mechanical and molecular motion, chemical effect; and all these have an exact mechanical equivalent. Conversely, mechanical power may be transformed into other forms of energy.

The gas burning in this room owes its brilliancy to the heat engendered by the clashing together, in chemical union, of the constituent atoms of the gas and of the oxygen of the atmosphere. The burners not only radiate light, but also heat; they are causing currents in the air of the room, and most of them are sending sound pulses more or less loud in all directions. I hold this thermopile next this jet; the galvanometer instantly indicates that a current of electricity has been set up; the energy represented by light and radiant heat has been converted into a galvanic current.

This glass rod, which I have already brought under your notice, will illustrate the converse principle. I rub it energetically, you hear a musical sound; the power of my arm has set the rod into longitudinal vibration, as you see by the vigor with which the little glass ball bounds from its end; that vibration has communicated musical pulses to the air. In addition, the rod has become hot, as you see by the indications of the thermopile, which has transformed a portion of the heat-energy into an electric current, competent to deflect the needle of the galvanometer; and, in addition, the gold-leaf electroscope shows that frictional electricity has been developed. This experiment demonstrates how wide is the field in which we must search in order to collect all the reactions corresponding to any particular mechanical effort. The debtor side of the account is generally composed of only one item, but the creditor side is made up of expenditure in many directions, and in that respect bears a strong resemblance to the same side in ordinary financial transactions.

The ultimate source of all energy is the sun. I cannot stop to discuss the various theories as to whence the solar heat originally came, and how the enormous waste continually going on is made good. I must content myself with stating that the compound rays emitted by the sun warm the earth, producing vast movements of water, in consequence of evaporation and the formation of clouds, and so we have warmth and moisture, upon which the growth of the vegetable and animal kingdom depends. Vegetation, as you are probably aware, derives most of its food not from the earth, into which its roots penetrate, but from the air. The lovely mantle of green leaves which adorns the productive portions of our planet is not intended to beautify alone; the vast surface exposed to the air has the property, under the influence of the actinic or chemical rays of the sun, of decomposing the carbonic acid in the atmosphere, of assimilating the carbon, converting it into the ligneous part of plants, and rejecting the oxygen, which is, however, essential to the life of animals, by whom it is inhaled, and, again rejected, restored to the condition of carbonic acid.

The quantity of carbonic acid in the atmosphere is relatively small, varying from three parts by measure to ten parts in 10,000, but, absolutely, the weight of carbon thus diffused is greater than all the carbon in the solid form on the face of the earth.

The sources of carbonic acid are the expirations of animals, the combustion of vegetable and animal substances, and emanations of a volcanic character. Wood contains from 46 to 55 per cent. of carbon, all derived from the atmosphere; and because the quantity of carbonic acid there is so small, an immense leaf surface is necessary to collect sufficient for the growth of the plant. By long continued contact with moisture and warm air, wood slowly decomposes by combining with oxygen, and is converted, according to circumstances, into vegetable mould, peat, lignite, or, finally, into coal, which, in the form of anthracite, consists of almost pure carbon.

The work done by the sun's rays in decomposing the carbonic acid of the air is very great. The energy which must be exerted to separate the carbon from its oxygen is the same as that developed by the combination of the same elements in combustion, and has been determined, by experiment, to be equal to 14,544 units of heat per pound of carbon consumed. By an easy calculation it can be deduced that every ton of carbon separated from the atmosphere in twelve hours involves energy represented by 1,058 horse-power expended by the sun, but as this energy operates over an enormous leaf surface, its effects are quite imperceptible to our senses.

The mechanical view to take of fuels is, that their component elements are in a state of potential energy with respect to the oxygen of the air, or, as in the case of explosives, with respect to each other. This energy has a strictly definite value for each kind of fuel, just like the potential energy of a body of water is a perfectly definite quantity with respect to its available fall.

The precise amount of this energy has been determined by many experimentalists, and especially by Favre and Silbermann, who, between the years 1845 and 1852, carried out an admirable series of experi-

* Lectures recently delivered before the Society of Arts, London.

ments, the substantial accuracy of which has been confirmed by subsequent investigations.

Their method of experiment was to carry on the combustion of various substances in oxygen and other gases in a small chamber surrounded by water, and fenced about with elaborate precautions against loss of heat by conduction or radiation. The water was kept agitated, and by the increase of its temperature the number of units of heat due to combustion was calculated.

The table below gives the calorific value of different substances which enter into the composition of ordinary fuels.

The general conclusions arrived at by Favre and Silbermann, Berthelot, and others, are that, as a rule, there is an equality between the heat disengaged or absorbed in the acts respectively of chemical combination or decomposition of the same elements, so that the heat evolved during the combination of two simple or compound substances is equal to the heat absorbed at the time of their chemical segregation, and the quantity of heat evolved is the measure of the sum of the chemical and physical work accomplished in the reaction.

The theories we have been discussing would naturally lead to the latter conclusion. The molecular energy set up by the conversion of the potential energy of the fuel into the kinetic form would most probably be expended in part, in the case of compound bodies, in the work of breaking up their structure before fresh combinations could take place, and, on the other hand, we can conceive chemical combinations of a nature that, on breaking up, would yield heat. Thus, carbon burned in protoxide of nitrogen, or laughing gas, N_2O, produces about 38 per cent. more heat than the same substance burned in oxygen; whereas in marsh gas, or methane, CH_4, the energy of combustion is considerably less than that due to the burning of the carbon and hydrogen separately.

Nearly all fuels consist of carbon, hydrogen, and oxygen. It is convenient to reduce the hydrogen to its heat equivalent of carbon. The table tells us that hydrogen develops 62,032 units per pound, while carbon develops only 14,544, so that hydrogen gives out 4·265 times more heat than carbon, and may be thus represented by it: H = 4·265 C.

I have already remarked that, in dealing with gases near their points of liquefaction, great circumspection must be used. The case of the combustion of hydrogen offers an excellent illustration. Favre and Silbermann condensed the products of combustion, and so determined the total quantity of heat developed, which included the latent heat of evaporation; but in furnaces the water formed in the combustion of hydrocarbon fuels passes off in the state of vapor, hence the latent heat of evaporation is not available. One pound of hydrogen burns to 9 lb. of water, the latent heat, at 212°, is 966 units, hence we must deduct 966 × 9 = 8,694 units from the tabular value of the heat due to the combustion of hydrogen, which leaves only 53,338 units available; therefore, the value in terms of carbon is $H = \frac{53338}{14544} C = 3{\cdot}67\ C$, or 14 per cent. less than if the vapor formed were condensed to water. I am indebted to Mr. Deering, of the Chemical Department of the Royal Laboratory at Woolwich, for pointing out to me this important correction which appears to have escaped the acuteness of even so careful and profound a writer as the late Professor Rankine.

The oxygen in fuel exists, for the most part, united to hydrogen in the form of water, and is, therefore, already in chemical union with a portion of the hydrogen, and incapable of further work; hence the equivalent weight, or one-eighth of the oxygen, should be deducted from the hydrogen before it is reduced to its equivalent value of carbon. The calculation takes this form when the water passes away in the state of vapor—

$$\text{Heat of combustion} = 14{,}544 \left\{ C + 3{\cdot}67 \left(H - \tfrac{O}{8} \right) \right\}$$

The formula does not always apply exactly, as, for example, in the case of marsh gas, where the heat developed is less than that due to the separate combustion of the carbon and hydrogen, namely, 23,513 units only, against 26,416, the theoretical amount.

The case of gunpowder is peculiar in every way. The chemical reaction which takes place is not very well understood. Powder contains all the ingredients of combustion in itself, and is not dependent on the oxygen of the air. The conversion into gas is very imperfect, only 43 per cent. becoming gaseous, while 57 per cent. is shattered into a very finely divided state, ultimately forming the smoke which characterizes the explosion of powder.

In comparing the calorific value of fuels, it is desirable to associate with them the air necessary for their combustion, because, by doing so, self-contained combustibles, such as explosives, can be brought into the category. When the chemical composition of any fuel is known, it is easy to calculate the quantity of oxygen required to insure complete combustion, and remembering that this gas constitutes about 22 per cent. of the weight of the atmosphere, the weight of air is easily arrived at. In the table above is given the chemical composition of different kinds of fuel, the units of heat derived from the complete combustion of a pound of each, the corresponding weight of water evaporated from and at 212°, and the weight of air required for combustion.

You will observe that gunpowder stands apparently in a very unfavorable position, yielding only 1,300 units against nearly 15,000 for some kinds of coal, but the comparison is not fair, because the other kinds of fuel are in an imperfect state. To make them self-contained, like gunpowder, we should add to each the weight of air necessary for its combustion, and then we get a singular uniformity in the units of heat per pound of complete fuel, as you will see by inspecting the last column in the table; and as in gunpowder there is no less than 57 per cent. of inert matter, so in the complete fuels no less than 72 per cent. is inert under the most favorable circumstances.

I have already given you Berthelot's first law of thermo-chemistry. I will now add two others:

2. When a system of bodies, simple or compound, starting from a given condition, undergoes chemical changes which bring it into a new condition without producing any mechanical effect on external bodies, the amount of heat evolved or absorbed as the total result of these changes depends solely on the initial and final states of the system, and is the same whatever may be the nature or order of the intermediate states.

An illustration of the application of this law occurs in the combustion of carbon when in thick layers.

The fuel near the bars is completely oxidized, and passes into the mass of glowing carbon above it in the form of carbonic acid gas, composed of one equivalent of carbon united to two equivalents of oxygen. In the mass of heated fuel the carbonic acid yields up one equivalent of oxygen to the carbon, and reaches the surface of the fire in the form of carbonic oxide, and here, meeting with a supply of air, the oxide burns, with a pale blue flame, to carbonic acid again. Berthelot's second law tells us that the intermediate reaction in the mass of glowing fuel does not affect the final result as far as the development of heat is concerned, so that, for the purpose of estimating the thermal value of fuel, all we require to know is its original composition and the final chemical nature of the products of combustion.

Berthelot's third law states, "that in any chemical reaction between a system of bodies, not acted on by external forces, the tendency is toward that condition, and toward those products, which will result in the greatest evolution of heat."

This law, therefore, furnishes a guide when calculating the heating power of fuels of complex structure, and which may oxidize into various substances, as to which combination is most likely to take place, for it tells us that we must select those reactions which will yield the most heat.

The table I have presented to you is calculated in accordance with the above laws. The heat equivalents of the elementary bodies, of march gas and olefiant gas, have been arrived at by direct experiment. The effects due to the explosion of gunpowder have been derived from the splendid and truly practical experiments of Sir Frederick Abel and Captain Noble. Mr. Deering has very kindly revised my calculations, and made some important corrections, based upon the most recent information we possess respecting the chemistry of fuels.

As it is my especial object to apply the doctrine of Carnot to the conversion of heat into useful work, it is necessary now to determine the highest temperature which can be obtained by chemical reaction.

It is much to be deplored that we have not, as yet, a trustworthy pyrometer capable of indicating temperatures above the melting point of platinum; we are therefore reduced to the necessity of being content with calculations. In these calculations, there are several elements of uncertainty.

First, as to whether combustion is complete; secondly, as to the quantity of air entering the furnace; thirdly, as to whether the specific heats of the gases are not subject to variation at very high temperatures; and, lastly, the part played by dissociation. There is a certain temperature below which the energetic chemical reaction which we call combustion cannot take place. Thus, coal gas cannot be ignited below red heat, say 1,000°, and carbon requires a much higher temperature. Anything in the arrangement of a furnace which tends to cool the fuel below the temperature of combustion will lead to imperfect action. Sir Humphry Davy availed himself of this fact in constructing his safety lamp.

Explosive gases, though they freely pass through the meshes of wire gauze, are so cooled by contact with the comparatively cold metal, that though they may be burning on one side of the gauze, the combustion ceases as the gases pass through.

I have here a small coal gas flame, over which I hold pieces of ¼ inch gas pipe of various lengths. You see that the flame passes through the shortest piece, while the longer one extinguishes it. The reason is that in the former case the surface of the tube was not sufficient to abstract the heat from the flaming gas, so as to lower the temperature below that of combustion, while in the latter case it was. That the nature of the gas has not been altered in any way is proved by the circumstance that it can be lighted as you see, on issuing from the top of the tube.

In the construction of furnaces, the facts above stated must not be lost sight of. So long as chemical reaction is taking place, all that tends to cool any portion of the gas should be avoided.

Mr. Frederick Siemens has carried this principle into practice with great success in the regenerative gas furnace. It was formerly considered that the smaller the furnace, and the closer the flame approached the objects to be heated, the better the result, but Mr. Siemens has boldly deviated from this doctrine. He has greatly enlarged the volume of the furnace. He introduces the gas and air at a moderate distance from the sides, bottom, and top, and increases the span of the flame so as to insure complete combustion before the opposite side of the hearth is reached. The flame thus forms an isolated body, acting by radiation from the

PROPERTIES OF FUELS.

	Composition by weight.						Units of heat per lb.	Pounds water evaporated from and at 212°.	Pounds dry air to one pound of fuel.	Calculated rise of temperature due to combustion.	Units of heat per pound of complete fuel.
	Carbon.	Hydrogen.	Nitrogen.	Oxygen.	Sulphur.	Ash.					
Atomic weight	12	1	14	16	32						
1 Durham coke	93·78	...	...	...	·82	5·4	13,640	14·12	10·91	4,877°	2,145
2 Anthracite	90·39	3·28	·83	2·08	·91	2·61	14,608	15·81	11·53	4,856°	2,173
3 Newport steam coal	81·47	4·97	1·63	5·32	1·10	5·51	14,743	14·64	10·99	4,830°	2,180
4 Wigan cannel coal	80·07	5·52	2·12	8·09	1·50	2·70	14,051	14·55	10·92	4,800°	2,176
5 Wolverhampton ten-yard seam	78·57	5·89	1·84	12·88	·39	1·03	13,920	13·86	10·41	4,765°	2,174
6 Petroleum	85·	15·	...	...	.	..	20,363	21·08	15·07	4,900°	2,267
7 Oak wood (dried at 284°)	49·95	6·	1·13	41·27	...	1·65	7,713	7·08	6·18	4,287°	1,089
8 Illuminating gas, by weight	61·26	25·55	8·72	4·47	...	...	20,801	21·53	15·66	4,567°	1,949
9 { Do. do. per 1,000 cubic feet, at 30" pressure, 60° Fahr. = 29·685 lb. }	lbs. 28·19	lbs. 7·58	lbs. 2·59	lbs. 1·33	...	...	Per 1,000 cubic ft. 617,485	639	465	...	...
10 Gunpowder	Charcoal. 14·2	Water. 1·	Nitre. 74·7	...	10·1	...	2,309	...	None.	3,960°	1,300

NOTES TO THE TABLE OF FUELS.

By W. H. DEERING.

Column 2.—Units of heat per 1 lb. consumed.—The numbers given under this column are calculated with values for the heat of combustion of hydrogen, of marsh gas, and of ethylene, which assume that the water produced by their combustion remains in the gaseous state; an assumption rendered necessary for the requirements of column 3, where the products of combustion are to heat water already at 212° Fahr.

The heat of combustion of carbon is taken as 14,544 lb. degrees (Fahrenheit), that of hydrogen as 53,339 lb. degrees, and the hydrogen available as fuel is supposed to be given by: Total hydrogen—⅛ oxygen.

No allowance is made in the calculation of the coals for evolution of heat in the burning of the small quantity of sulphur, there not being adequate data.

The heat of formation of the different coals not being certainly known, these calculated numbers for heat of combustion will be useful for comparison, but must not be taken as the quantities that would actually be obtained.

In the case of illuminating gas (No. 8), which is taken as dry, the total heat of combustion, given under column 2, is calculated from the constituents, hydrogen, marsh gas, carbonic oxide, etc., using the respective experimentally obtained values.

In the case of petroleum, the numbers given for the calorific power of petroleums No. 6 A and 6 B are corrected experimental numbers, obtained by Deville, who worked on a large scale.

The correction of Deville's experimental number for calorific power consists in the deduction of the latent heat of the water, produced by the combustion of the petroleum; he having cooled his chimney gases, and liquefied the water.

The calculated number for 6 B is about 1,500 units, or about 1-12 higher than the experimental; partly to be accounted for by the heat of formation of the petroleum being a positive quantity.

Deville also determined the calorific power of Baku petroleum, and found it to be somewhat higher than that of Pennsylvanian petroleum. The experimental number was 700 Fahrenheit units (or 1-20) lower than the number obtained by calculation from the percentage composition of the petroleum.

Column 4.—Weight of dry air required for combustion.—An allowance is made for the air required for the combustion of the sulphur contained in the coal and coke. It is regarded as half being in combination in the non-mineral part of the coal, and half being present as iron pyrites. The sulphur is supposed to be burnt to SO_2, and the iron to ferric oxide, when on the above suppositions 1 lb. sulphur requires 4·89 lb. of air. It does not much matter if the fundamental suppositions are not wholly correct, as 1 per cent. of sulphur so calculated requires only 0·05 lb. of air when 1 lb. of coal is burnt.

Column 5.—Maximum Rise of Temperature.—The specific heats of the products of combustion, carbon dioxide, gaseous water, and of the nitrogen of the air, used in the calculation of maximum rise of temperature are 0·217, 0·48, 0·244 respectively; and are the specific heats of these gases at constant pressure.

The numbers given under this column have some value for the purpose of comparison, but must not be taken as temperatures actually attainable. First, because dissociation of the elements of CO_2 and H_2O would take place at temperatures much below those given; the consequence of which would be that, at the hottest place of combustion, there would be some unburnt, and there unburnable, carbonic oxide and hydrogen.

Secondly, because the specific heats of gaseous water, of carbon dioxide, and of nitrogen are probably higher at the maximum temperatures of the combustion of the different fuels than the values used for the calculation of column 5. The rise with temperature of the specific heat of carbon dioxide has long been known to be very considerable even at low temperatures, and recent researches of Berthelot and Vieille render it more than probable that there is also a great rise in the specific heats of gaseous water and of nitrogen at high temperatures. The use of these higher values for the specific heat of the gases mentioned would, of course, lower the calculated maximum rise of temperature.

brilliantly incandescent particles of carbon alone, and the practical result attained is, a higher temperature, due to complete combustion; an increased durability of the furnace, due to the circumstance that the firebrick is not exposed to the erosion caused by the friction of the highly heated gases; and, lastly, less deleterious effect upon the substances being heated. The same principle he has applied to boiler furnaces. By placing rings of firebricks at intervals in the flues, he keeps the flame from contact with the boiler plates. It parts with its heat by radiation alone, until the chemical reaction is complete, and then the heat may be abstracted from the products of combustion by con-

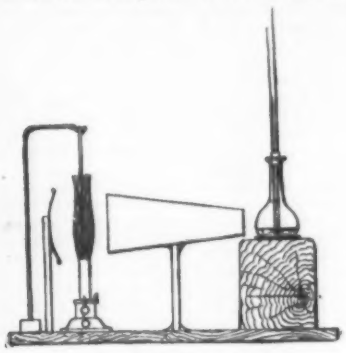


FIG. 22.—BUNSEN BURNER.

tact, either in passing through small tubes or in any other way. I have here a model for a horizontal flue constructed in mica, which Mr. Siemens has kindly lent me. Rings of brass serve to confine the body of flame which you see passing along the tube, but kept completely from contact with it.

Mr. Siemens' method of heating furnaces by radiation is specially applicable when the flame is luminous, that is to say, charged with white-hot particles of carbon. A pale non-luminous flame, such as you see in a Bunsen burner, has very little radiating power, because air, nitrogen, and carbonic acid, which form the bulk of such flame, are very bad radiators of heat. The vapor of water is a good radiator, but it forms a very small portion of the products of combustion. Solid carbon, on the other hand, is an excellent radiator and absorber, and on that account a mass of flame charged with it will radiate heat powerfully. I have here a Bunsen burner (Fig. 22, above), arranged so that the radiation from the flame can be concentrated by a concave mirror and cone on the blackened bulb of a large air thermometer. This luminous and comparatively cold flame has been burning since the commencement of the lecture, and the thermometer has now attained its maximum height. I admit air, and convert the flame into an intensely hot but non-luminous one. You see that the thermometer rises very little, but if I hang a spiral of wire in the flame, it begins to glow and to radiate its intense heat powerfully, causing the thermometer to rise rapidly.

Smoke in furnaces is not altogether an evil, because it serves the purpose of the spiral wire; it improves the radiating powers of the hot products of combustion.

In an ordinary furnace the fuel is in the most disadvantageous condition for complete combustion. It lies in large lumps loosely on the grate, with large and irregular interstices, through which the air and gases evolved have to make their way. In many places the streams of air are so thick that they do not come intimately into contact with the fuel at all, and pass through nearly unchanged, hence, as a rule, a large ex-

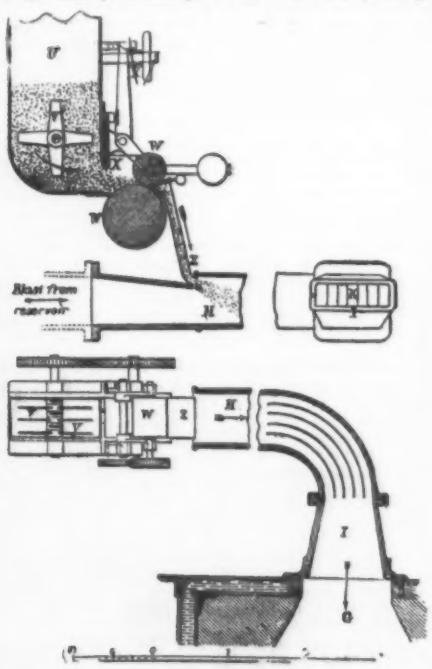


FIG. 23.—CRAMPTON'S DUST-FUEL APPARATUS.

cess of air, amounting generally to 50 per cent., has to be admitted. In addition, the combustible gases evolved are, in places, cooled below their points of combination by contact with large masses of air, and hence free carbonic oxide and particles of unconsumed carbon are generally found associated with the products escaping by the chimney.

By mechanically subdividing the fuel, and mixing it intimately with only the proper weight of air, the completeness and intensity of combustion may be greatly enhanced. Such a disposition we have in Mr. Crampton's dust-fuel furnace. The fuel is reduced to the finest possible state of subdivision—so fine as to pass through a sieve of 100 meshes to the inch—by means of a disintegrator or a pair of mill-stones; it is then conveyed into a hopper, furnished with agitators, which force it through an opening, the width of which can

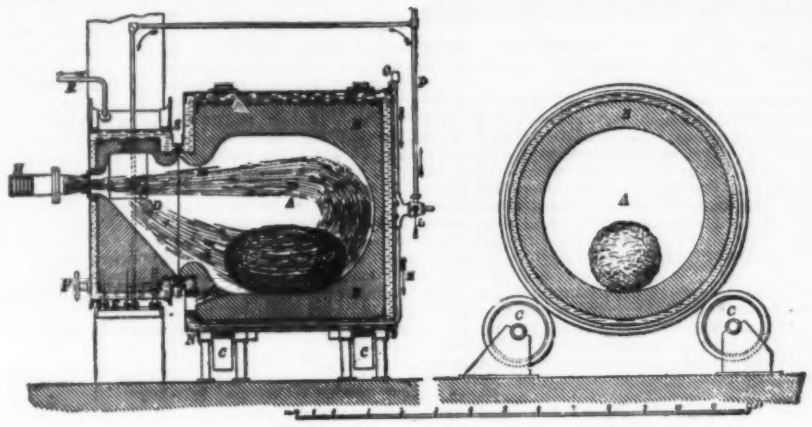


FIG. 24.—CRAMPTON'S DUST-FUEL FURNACE.

be regulated at pleasure, into a pair of rollers, which feed the fuel at a uniform rate into a slit in a pipe, along which a blast of air is passing. The dust mixes intimately with the air, and is carried along by it into the furnace, where it at once flashes into flame, of a temperature so intense that wrought iron can be easily melted. Simple as the process is, it has taken the inventor many years to overcome the minor difficulties which surrounded the practical application. One of these consisted in turning corners with the blast pipe. The particles of coal, in obedience to the first law of motion, tended to maintain a rectilinear course, and could only be turned from it by the bent sides of the pipe; the consequence was that where a bend occurred the coal-dust separated from the air, and collected along the concave side of the pipe. By introducing a number of parallel curved partitions into the bend this action was, in a great measure, neutralized. Another difficulty lay in the erosive action of the particles of solid fuel on the brick lining of the furnace, but this has been overcome by the use of water-jackets, and by the proper direction given to the flame. By the kindness of Mr. Crampton, I am enabled to bring before you diagrams of his revolving puddling furnace heated by dust fuel, and the same system adapted to marine boilers, with which some extensive experiments were made at Sheerness by the Admiralty in 1872–73, with satisfactory results. It is obvious that the proportion of air and fuel, and the rate at which both are supplied, can be accurately adjusted, and, as a matter of fact, Mr. Crampton finds that he can use the theoretical proportion of air required by the coal, and at the same time secure complete combustion and total absence of smoke. The consequence is, that the chemical action is so energetic that a very high temperature is reached at once with cold air and cold fuel. The manual labor connected with the system is really confined to supervision; it would seem therefore peculiarly fitted for steamships, where stokers are exposed to so much hardship, especially in tropical climates, and where their cost is a serious item in the expenses of a voyage.

The tonnage necessary for the accommodation of stokers, and the stores required by them, would probably exceed the space which grinding machinery would occupy. It is much to be regretted that the distinguished engineer, who is the author of a process scientifically correct and eminently practicable should not devote himself to its more extended introduction, especially as all the difficulties connected with the system appear to have been completely overcome. In the case of liquid fuels, such as petroleum, a similar intimate mixture with the air can be attained, and the relative quantity of each regulated. The apparatus now invariably used is some form of injector, by means of which, through the agency of a jet of steam or compressed air, the fuel and air are introduced into the furnace. One of the most successful applications to locomotives is that made by Mr. Urquhart, the engineer of the Grazi and Tsaritsin railway, in Southeastern Russia. The Figs. 25 and 26 above illustrate his method. The injector is of the ordinary circular type, impelling a solid jet of steam and petroleum, surrounded by a current of air, through a tube traversing the water space at the bottom of the firebox. To keep up the temperature of the flame during combustion, the oil is thrown into a brick oven, built upon the ash-pan, and from thence it is distributed, by numerous openings, into the firebox, where the chemical reaction is completed, and the heat afterward absorbed by the boiler tubes. On the Volga and the Caspian Sea, petroleum refuse has now almost superseded all other fuel in marine boilers. One of the forms of apparatus in use is illustrated in Fig. 27.

The injector, in this case, delivers a hollow cone of oil. Air is introduced both inside and outside the jet, so that the mixture is still more intimate than in the arrangement adopted by Mr. Urquhart. The furnaces are not always lined with firebricks, but from what I have already said, it is obvious that a lining would tend very much to promote complete combustion, and would, at the same time, protect the boiler plates from the intense heat engendered in the immediate vicinity of the flame as it is first formed.

A still finer subdivision of particles is attained when the fuel is made to assume the gaseous form before combustion sets in. We have a splendid illustration of this method in the Siemens regenerative gas furnace. According to this system, a crude gas is manufactured in a species of oven called a "producer" (Fig. 28, p. 8005). The oven is of peculiar shape, and is fitted with

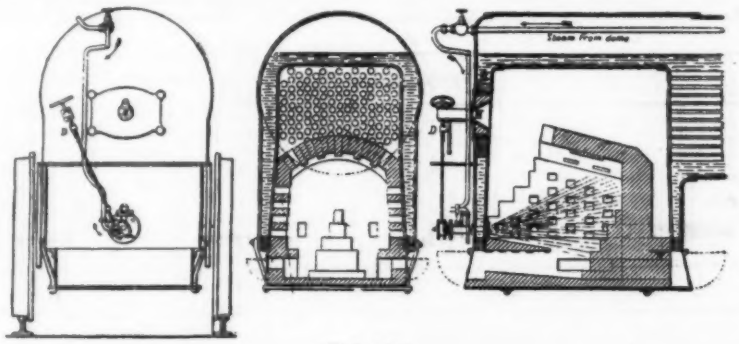


FIG 25.

a fire grate at the bottom. A considerable depth of fuel is kept on the bars. The layer, in immediate contact with the air entering between the bars, burns to carbonic acid, and the energy of this reaction raises the temperature of the carbon to a red heat, at which the carbonic acid is decomposed by taking up an additional equivalent of carbon, and carbonic oxide gas flows up into the producer. The heat of the lower layer of fuel causes the hydrocarbon gases in the upper to distill, so that a mixture of various inflammable gases and nitrogen becomes available for use. The gases rise into the furnace, which they enter, accompanied by the proper quantity of air, and unite with it, much as we see in an ordinary Bunsen burner. It is obvious that the intimacy with which the gas and the air may be made

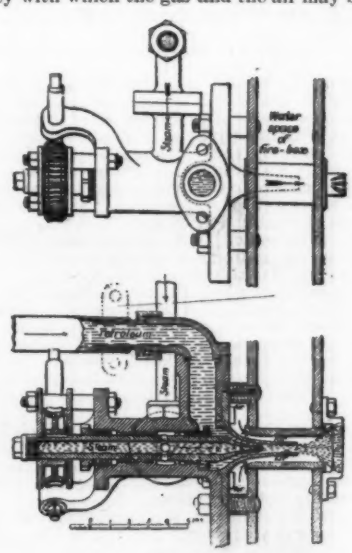


FIG. 26.

to mix, the relative proportion of each, and total rate of combustion, must be capable of the most exact control.

There is one method by which the combustion of solid fuel on ordinary grates may be ameliorated, and that is by the use of forced draught. The feeble pressure obtainable from an ordinary chimney necessitates thin and loose layers of fuel, but when air can be blown in, the layers may be increased in depth, and made more compact, so that the air is brought into more intimate

contact with the combustible. By this means the quantity of air may be reduced to the theoretical amount, and the temperature of the furnace exalted in proportion.

Little or nothing has been done to investigate the specific heat of gases at high temperatures, so that the uncertainty of calculations depending on an accurate knowledge of this property must still remain.

The investigations of St. Claire-Deville have revealed that, at high temperatures, compound gases become resolved into their elements, and that chemical combinations cease to take place. This phenomenon is called "dissociation."

According to laboratory experiments, water and carbonic acid commence to dissociate at about 2,500° Fahr. absolute, and this action has an important bearing upon the temperature which a furnace is capable of attaining, although it evidently does not fix the limit, because it is certain that wrought iron and platinum can be melted in a coal fire, although the fusing point of the metals is about 3,500° absolute. We shall probably not be far wrong if we assume 4,000° absolute to be the superior limit of temperature of any furnace, a limit which, if the theory of dissociation be correct, can never be surpassed. The invention of a trustworthy pyrometer will alone be able to yield more definite information on this subject.

We may assume that the specific heat of coal, and of the products of combustion at constant pressure, are the same as that of air, namely, 0·238, and it is highly probable that by the use of forced draught, of properly constructed grates, or of powdered, liquid, or gaseous fuel, it may be possible to insure perfect combustion with only the quantity of air required to supply the exact weight of oxygen necessary to combine with the elements of the fuel. Under such circumstances, it is not difficult to calculate the temperature of the furnace when we know the units of heat a pound of fuel is capable of yielding, for it is only necessary to divide that value by the product of the weight of fuel and air into the specific heat, and add the quotient to the temperature of the air. Hence—

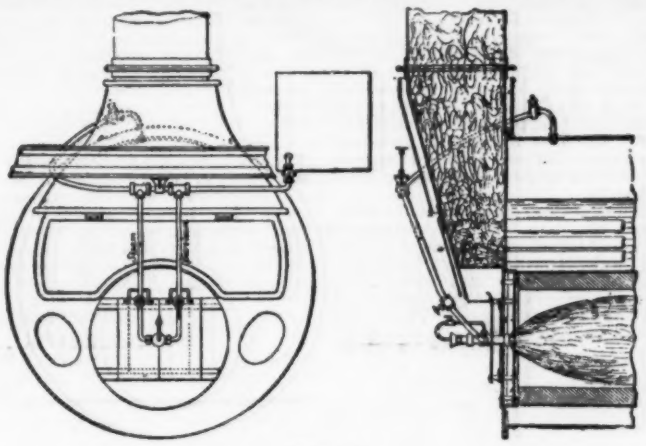


FIG. 27.

$$\text{Rise of temperature} = \frac{\text{Units of heat}}{\text{weight of complete fuel} \times 0{\cdot}238}$$

Take the case of Durham coke, for example—

$$\text{Rise of temperature} = \frac{13{,}640}{(1 + 11{\cdot}5) \times 0{\cdot}238} = 4{,}588°, \text{ and}$$

here we are at once met by a consideration which too often escapes notice, namely, the effect of the pressure of the atmosphere under which we live on all the operations which we perform. The effect of combustion is to convert solid fuel into an immensely greater volume of gas; 1 lb. of Newport steam coal, for example, when burned with the least possible air, produces 147 cubic feet of various gases at 32° Fahr. or 492° absolute. If the temperature of the furnace rises from 50°, or 510° absolute to 5,376° absolute, the volume will be increased in the proportion of the absolute temperatures, or as $\frac{5{,}376°}{492°}$ or a little more than eleven-fold, so that each pound of coal will yield 1,606 cubic feet, and in order to make room for this volume, the atmosphere must be moved aside at the cost of work = 1,606 cubic feet × 144 sq. in. × 14·7 lb. = 3,400,100 foot-pounds, equal to the conversion of 4,404 units of heat, or 30 per cent. of the whole heat of combustion. If the action could be carried on *in vacuo*, there would be no appropriation of heat to the work of displacing the air, and then the temperature of the furnace would be much higher, namely, in the case of Newport steam coal, it would rise from 5,376° absolute to 7,362° absolute, an increase of 36 per cent. The coefficient for the specific heat of gases which we have employed allows, as you may remember, for this external work done during expansion.

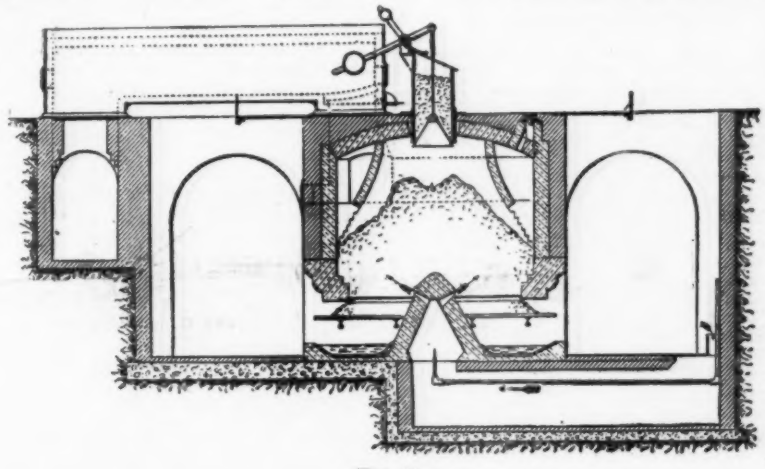


FIG. 28.

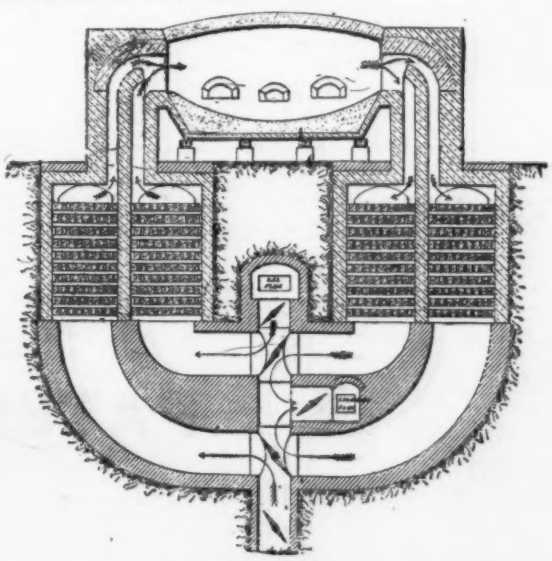


FIG. 29.

In any practical applications of fuel, we cannot arrange for the products of combustion to escape at a lower temperature than that of the surrounding air, and generally the temperature is much higher. Assume, as an extreme case, that the products of combustion have fallen to 50°, or 510° absolute, the gases will have shrunk to

$$\frac{147 \text{ c. ft.} \times 510°}{492°} = 152 \text{ cubic feet,}$$

and the work done will be 152 c. ft. x 144 sq. in. x 14·7 lb. = 322,500 foot pounds, corresponding to 418 units of heat, or nearly 3 per cent. of the total heat of combustion. The work expended in displacing the air in the furnace is restored again as the gases cool, but the final loss, just calculated, is complete and irrevocable.

What, then, is the limit of efficiency in the combustion of fuel?

We must apply Carnot's theory; and assuming that 4,000° absolute is the maximum temperature to which we can attain, and 510° absolute the lowest, we have—

$$\frac{4{,}000° - 510°}{4{,}000°} = 0{\cdot}872;$$

that is to say, under the exceptionally favorable circumstances I have taken, there must be a loss of 13 per cent. It may not, at first sight, be very apparent why the high temperature of the furnace should increase the efficiency when the smoke escapes at the same temperature in either case, and the same quantity of heat is yielded by combustion, but the explanation is simple. The cause of the reduction of the temperature of a furnace is the introduction of an excess of air; this air passes out by the chimney, and carries off heat in proportion to its weight; hence, in all cases where it is desired to attain the highest efficiency in the use of fuel, the aim must be to use as little air as possible, so as to raise the temperature of the furnace to the utmost, and to cool down the smoke usefully as much as possible.

Under ordinary circumstances, at present at least, 50 per cent. excess of air is admitted into furnaces, and the chimney temperature rarely falls below 400°; this reacts unfavorably on the duty of fuel at both ends of the operation. Supposing 16·5 lb. of air admitted to Newport steam coal, the rise of temperature of the furnace would be reduced to—

$$\frac{14{,}143u}{17{\cdot}5 \times 0{\cdot}238} = 3{,}396°,$$

and the smoke being at 860° absolute, the efficiency will be $\frac{3{,}906° - 860°}{3{,}906} = 0{\cdot}78$, or 78 per cent., and the water evaporated would be 14·64 x 0·78=11·42 lb. per pound of coal from and at 212°, which is very nearly the duty to which a good boiler can attain.

According to Carnot's doctrine, the temperature of the products of combustion should be reduced as low as possible, in order to attain the most economical results. In steam boilers it is possible, and practicable, to reduce the temperature to very little above the temperature of the feed water supplied, because it is more economical to produce the necessary draught by means of a blower than by means of a hot chimney. From experiments made by the Admiralty, it appears that a pressure of air equal to a column of water 1" high produces a very strong draught, much greater than that due to a chimney fitted with a steam blast. We have seen that one pound of coal requires practically 18 lb. of air to consume it; the volume of this at 50° = 231 cubic feet, and a pressure of 1" of water represents 5·2 lb. per square foot, hence the work done in forcing in the air will be 231 × 5·2 = 1,200 foot-pounds. Suppose we have a blower, driven by a small engine consuming 5 lb. of coal per indicated horse power per hour, and suppose the blower does only 50 per cent. duty, we should have 2,400 indicated foot pounds, and if this is done in a minute, then the units of heat absorbed by the engine would be:

$$\frac{5 \text{ lb.} \times 14{,}143u \times 2{,}400 \text{ foot pounds} = 88u}{60u \times 33{,}000 \text{ foot pounds}}$$

If the boiler had depended on chimney draught, the temperature of the smoke must have been at least 400°, and the loss of heat = 19 lb. × 0·238 × 350° = 1,582 °, or eighteen times as much as the blower would consume. But suppose that by the use of forced blast we were able to arrange a feed heater, so as to reduce the temperature of the chimney to 100°, or only 50° above that of the cold water fed in, then the heat saved per pound of coal would be 19 lb. × 0·238 × 300° = 1,356 units, more than fifteen times the heat absorbed by the blower, and competent to raise the 10 lb. of water fed in per 1 lb. of coal 135·6°, a temperature still far short of that of the boiler. Two things are apparent from this consideration, namely, first, that a decided economy will arise from blowing air into boilers by engine power, instead of drawing it in by means of a chimney; and secondly, that the feed water heater should be detached from the boiler, and made to do its work at the lowest temperature practicable.

In furnaces used in the various arts, such as in metallurgy, in glass, and chemical manufactures, it is, generally, impossible directly to reduce the temperature of the smoke to economical limits. In blast furnaces, the intense heat at the boshes is, in a great measure, taken up by the mass of fresh materials continually being added at the top, but in most cases, especially when steam is not required, the regenerative system has to be adopted.

The regenerator was, I believe, invented in the early part of this century, by Stirling, for his hot air engine. The principle is this: The hot body ejected from the heat engine passes through a vessel filled with metal plates, bricks, or any other substances presenting a large surface of contact, and being good absorbers of heat. The consequence is, that one end of the regenerator, that nearest the engine, becomes highly

heated, while the opposite end is comparatively cool. After a time the flow is reversed, and a cold current, which it is desired to heat, sets in toward the engine, and takes up the heat which the flow in the opposite direction has left in the regenerator.

The late Sir William Siemens adapted this system to furnaces working at high temperatures (see Fig. 29). He conducted the still glowing products of combustion to the chimney through chambers filled with firebrick, built up in reticulated fashion so as to present a large surface. The chambers were arranged in pairs, and the passages to them were controlled by valves. The air for the supply of the fire was led through one pair of chambers, and the gas through another, the valves being so manipulated that the flames would pass for an hour or two down chambers, A, while the air and gas passed upward through chambers, B; then the currents would be reversed, and the air and gas would enter by chambers, A, while the products of combustion descended by B. The chambers were made so deep that the maximum heat of the bricks extended a good way below the surface, and the duration of the flow of air and gas was so regulated that the layers of bricks nearest the furnace were not appreciably cooled, so that the temperature of the air and gas entering the furnace was practically constant. One end, therefore, of the regenerator was always at a constant high temperature, and the opposite end at a constant low one, the maximum heat of the space between oscillating up and down, according as the cold current or the hot was passing through. It will be readily understood that such an arrangement must lead to a regular increase of heat in the furnace each time the current of air and gas is reversed. Imagine the furnace started for the first time. The air and gas would come up to the point of combustion cold, they would be increased in temperature by the heat due to the chemical reaction, and would communicate the surplus heat to one pair of regenerators, A. On reversing the valves, the fuel would enter the furnace at a high temperature, the heat corresponding to the energy of combustion would be added to this, the flame would be hotter, and regenerator, B, would be more highly heated than A. On again reversing, the fuel would reach the hearth still hotter than at the previous turn, and the temperature of the flame would be again increased. A repetition of this process would lead to temperatures which no material, however refractory, would stand; but here dissociation steps in and puts a salutary limit to the temperature which can be attained, a limit which we have assumed to be about 4,000° Fahr. absolute. The effect of the regenerators on the duty of the furnace is easily calculated. The temperature of the products of combustion leaving the regenerator is reduced to about 250° Fahr., or 710° absolute, and this fall has taken place in heating up the air and gases entering the furnace, and, therefore, is doing useful external work; hence, we must consider the furnace and the regenerator as an engine working between our assumed maximum of 4,000° absolute and a minimum of 710°; consequently, the duty to be expected from the fuel will be—

$$\frac{4{,}000° - 710°}{4{,}000} = 0{\cdot}82.$$

Without the regenerator, the product would have escaped at a bright red heat, at least 1,500° or 1,960° absolute, and the duty would have been

$$\frac{4{,}000° - 1{,}960°}{4{,}000} = 51;$$ hence, the regenerators secure an economy of 31 per cent.

In a recent paper read at the Iron and Steel Institute, Mr. Siemens stated that careful experiments with an ordinary reheating furnace, using solid fuel and a regenerative gas furnace, showed an economy of 33½ per cent., which approaches very closely to the result deduced from these purely theoretical considerations.

The regenerative principle is capable of application wherever the products of combustion are not reduced directly to a very low temperature, as they may be, for example, in steam boilers. Thus, the waste heat of a Crampton furnace has been utilized in heating the air and fuel before it enters the furnace, and in raising steam while Mr. Urquhart has applied the principle partially to warming some of the air as it enters the firebox. In his arrangement, only a portion of the air required enters with the jet of petroleum, the rest is admitted through passages made in the lower part of the brick oven, through apertures in the ash pan; the heat which should otherwise produce very little effect on the boiler, is thus made profitable use of.

SANATORY PRECAUTIONS IN THE DWELLING.

E. DWIGHT KENDALL.

"*It happens, accordingly, that when this corrupt air has at length joined our air, it infects it, and renders it like itself, and unsuitable for us.*"—Lucretius.

IN every household, means should be adopted to avoid dangers from sewer-gas, cellar-air, air from between the walls and under the floors, close air in sleeping rooms, and the poison of impure water, any of which may cause zymotic disease. Do not depend on disinfectants, but bar the entrance of all foul air. You cannot rely on traps to keep out sewer-gas; it should be a strict rule in every family, that the waste-water pipe must be closed after using a wash-basin. Stop the "overflow" opening *permanently;* several devices are purchasable that are well adapted to close that connection with the sewer; this may also be done by cementing a piece of rubber or varnished cloth over the apertures or by filling them with pitch or plaster of Paris; if plaster be used, mix it with water to the consistency of thick paste, press this into the holes, and when it has hardened and become dry, imbue it with vaseline or varnish; its expansion in hardening fastens it in place, and it will remain a long time, impervious to water and air. Damage from accidental overflow may be prevented by using self-closing faucets, or, as a temporary expedient, the ordinary projecting delivery-pipe may be made self-closing by connecting with it one end of a piece of elastic rubber tube or band, the other end being fastened to a suitable fixed point.

Next to sewer-gas the worst enemy may be cellar-air. Beneath the pavements of cities, the earth is impregnated with foul organic and excrementitious matters, by percolation from the streets and leakage from soil-pipes and sewers; there being no vegetation (that, by its roots, removes such filth), the corruption accumulates and extends; its poisonous emanations pass through the pores of bricks and mortar (*e. g.*, the stench that pervaded the tunnel in Fourth Avenue) and permeate the ordinary cement of cellar floors. The best remedy is to have asphalt or several coats of *oil paint* applied to the walls and to the cemented floor. If the flooring is of wood, paint that, after stopping all cracks and holes with putty or plaster. Asphalt paving is impervious, and the best for cellars. In nearly all buildings the cellar-air diffuses itself throughout the house, through crevices in the flooring and pores of the thinly plastered walls.

An offensive smell was noticed in a certain dwelling, and ascribed to sewer-gas: "*No,*" said the builder, "*it is only house-air,*" and "house-air" it was, *i. e.*, that which becomes foul under the floors by the natural odors and excreta of rats and mice, and between the walls by leakage from the cast-iron soil-pipes which connect the water-closets with the sewer. These pipes are made in short sections, and often the junctures are not properly cemented, in some instances they have been merely placed together without cement of any kind. To prevent the entrance of "house-air," all floors should be made air-tight with putty and paint, and the large openings made by the plumber should be closed. The walls should be painted or varnished; surfaces of porous plaster or unvarnished paper constitute effective fomites (reservoirs of infection), while polished, impervious walls less readily become impure, and may be easily cleansed. The exhalations from the lungs and bodies of persons in health are sufficient not only to defile the air of a closed apartment, but also to impregnate porous walls with a persistent foulness. The benefits from a continuous supply of pure air in sleeping-rooms cannot be too often alluded to, in view of the general negligence and apathy, in this respect, of even the well-informed.

Of no less consequence than pure air is unpolluted water. The waters of small streams that flow through populous districts are always contaminated, and the theory is fallacious that perfect purification quickly results from the contact of air with the flowing currents. The sources of pollution have been often pointed out, and the unhealthful effects described. It is not only the water of open streams that is dangerous. "*Typhoid fever,*" said an experienced physician, at the moment he entered a room, at the further side of which lay the patient. The malady that presented such marked characteristics, and that brought a vigorously healthy person almost within the grasp of death, was caused by one glass of water, taken from a well. In certain places the prevalence of enteric fevers is clearly traceable to the wells, and often there is no apparent source of filth. An open well may receive putrescible bodies in various ways, and every well of still water, at times, contains organic impurity. Rain water from the roofs is filthy; besides the absorbed gases, that were evolved from decomposing matter, and the myriads of corpuscles gathered from the atmosphere, it is fouled by dirt blown from the roads and the droppings of birds; in warm weather it soon becomes offensive from putrefaction.

The purity of water cannot be known by the unaided senses; a clear and odorless water, of pleasant taste, may be deadly. The chemist can determine the quantity of contained albuminoid matter, but, even with the microscope, he cannot prove it innocuous. What waters are surely harmless? The living spring and water recently boiled. It is not troublesome to prepare boiled drinking water; the custom, when adopted, soon becomes but a small part of the kitchen routine. A simple method is to provide an enameled or cast-iron vessel for boiling the water, and two large stoneware jars, each having a faucet near the bottom; place the jars where only pure air can reach them, supporting one a foot or two above the other; pour the boiled water into the upper jar, and when it is cool adjust the faucet so that the water shall slowly drip into the lower jar; this exposure to air and the agitation caused by the falling drops will sufficiently aerate the water. A substitute for the jars is a single crock of large diameter having a cover of fine wire gauze or perforated tin-plate; but without agitation considerable time is required for the cooled water to absorb sufficient air to become palatable. It is well to filter the water before or after boiling it. Various appliances are in the market for that purpose, and perfect filtration may be effected simply by using a small conical bag, made of cotton-flannel (the fleecy side within), fastening this with wire or cord over the mouth of the water faucet. If the water is not delivered under pressure, let the bag be made to hold a gallon or more and pour the water into this.

Ice should never be put into drinking water; it holds much dirt mechanically, and is liable to become the vehicle of disease germs. It has long been the custom in the writer's household to have earthen Seltzer-water bottles filled with purified water and placed in contact with the ice.

It is not expected that every *paterfamilias* will recognize the importance of the above mentioned precautions, but due consideration should be given all suggestions that relate to preventable diseases.

THE COLORING MATTER OF FLOWERS AND FRUITS.

IN an interesting communication on the subject of the coloring matters in flowers and fruits, contributed to a society at Wurzburg (*Gard. Chron.*, June 20, p. 794), Dr. A. Hansen gives reasons for supposing that a relatively small number of pigments suffice for the production of the apparently endless variety of tints. Taking flowers in the first instance, and setting aside chlorophyl green, as being rarely met with in them, he recognizes three groups of colors: the yellows, the reds, and the blues and violets. White is due merely to the reflection of light through colorless tissues containing air, and blacks are attributed to a concentration of violet pigments. The yellow pigments are mostly in combination with plasmic substance, while the reds and blues and violets are generally found in the cell-sap. The yellow of flowers is said to form an insoluble compound with fatty matters, which it is thought might explain the comparative permanence of that color in plants. The pigments of different yellow flowers have been found to agree with each other in regard to their spectra so closely as to point to identity, and Dr. Hansen obtained by saponification with soda and extraction with light petroleum spirit a crystalline yellow pigment which corresponded in its behavior to the "lipochrome" obtained by Krukenberg from the animal kingdom. Orange is due to a denser deposit of the yellow pigment, the color in orange rind being referable to the same substance as that in the petals of *Ranunculus repens.* The pigment in yellow dahlias and lemon rind, however, behaves differently, both chemically and spectroscopically; it is soluble in water, and seems to be very similar to the pigment of *Æthalium septicum*, the yellow fungus or mould of rotten wood. The reds of flowers, Dr. Hansen reduces to a single pigment, the description of which so far as it goes appears to correspond to that given some years since by Mr. Harold Senier of a coloring matter isolated by him from the petals of *Rosa Gallica* (*Ph. Journ.* [3], vii., 794).

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